BC hydro

69 kV to 500 kV

INTERCONNECTION REQUIREMENTS

FOR

POWER GENERATORS

January 2002

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c) BC Hydro wishes to acknowledge the Bonneville Power Administration for certain selected material used in this document.

2. INTRODUCTION

This document provides information on BC Hydro's (BCH) 69kV to 500 kV Interconnection Requirements for Power Generators (PGs) by stating (a) the minimum technical requirements the Power Generators connecting must meet, and (b) identifying expected system conditions the connected facilities could encounter while connected to the BCH system. *Power Generator* is defined as a resource to produce electricity that is connected and synchronized to the BCH system. The Power Generator may consume all or some of the generated electricity on site or it may sell the generated electricity.

In general, the PG will own and is responsible for the design, installation, operation, and maintenance of all necessary equipment, station and transmission line facilities that are required to connect its facilities to BCH, unless otherwise agreed to in writing. The PG is responsible for obtaining all regulatory approvals, including environmental assessment approvals, if necessary, for the construction and operation of its facilities. The facilities shall be designed, constructed, operated and maintained in compliance with the applicable statutes, regulations, by-laws and codes.

The PG is also responsible for submitting all specifications of its facilities and detailed plans to BCH for review prior to receiving permission to connect to BCH.

3. FACILITY MODIFICATIONS

BC Hydro shall be notified during the design stage and prior to any alterations after full commercial operation of the PG facility has commenced. Changes that affect the PG's

reliability, fault contribution, generator performance, control, or protection schemes and/or settings require BCH's confirmation.

4. DISCLAIMER

This document is not intended as a design specification or as an instruction manual for the PG and this document shall not be used by the PG for those purposes. Persons using information included in this guide do so at no risk to BC Hydro, and they rely solely upon themselves to ensure that their use of all or any part of this guide is appropriate in the particular circumstances.

The PG, its employees or agents must recognize that they are, at all times, solely responsible for the plant design, construction and operation. Neither BC Hydro nor any of their employees or agents shall be nor become the agents of the PG in any manner howsoever arising.

BCH's review of the specifications and detailed plans shall not be construed as confirming or endorsing the design or as warranting the safety, durability or reliability of the PG's facilities. BC Hydro, by reason of such review or lack of review, shall be responsible for neither the strength, adequacy of design or capacity of equipment built pursuant to such specifications, nor shall BC Hydro, or any of their employees or agents, be responsible for any injury to the public or workers resulting from the failure of the PG facilities.

In general, the advice by B.C. Hydro, any of its employees or agents, that the PG's plant design or equipment meets certain limited requirements of BC Hydro does not mean, expressly or by implication, that all or any of the requirements of the law or other good engineering practices have been met by the PG in its plant, and such judgement shall not be construed by the PG or others as an endorsement of the design or as a warranty by BCH, or any of its employees.

The information contained in this document is subject to change and may be revised at any time. BCH should be consulted in case of doubt on the current applicability of any item.

5. SCOPE

The document will generally apply to all generating resources interconnecting to the BC Hydro transmission system. These requirements will ensure that the PG's equipment will:

a) At all times be compatible with and safe for the BCH system, for BCH employees and agents, for all BCH customers and for the general public;

b) Maintain a high standard of quality and reliability of electricity supply to BCH customers;

c) Meet BC Hydro operating, dispatching, metering and protection requirements.

d) Be consistent with the required regulatory agencies and authourities such as the British Columbia Utilities Commission (BCUC), and the Western Systems Coordinating Council (WSCC).

6. CONTACT WITH BC HYDRO AND OTHER AUTHORITIES

BC Hydro's Office of Generator Interconnections will co-ordinate all consultation and communication that the PG has with various groups within BCH on interconnection issues. The Office of Generator Interconnections is responsible to ensure that the appropriate groups within BC Hydro are informed as required about all aspects of the PG's project. The Generator Interconnections Office can be reached via e-mail at gen.connections@bchydro.com or phone at 604-528-3313.

The PG will communicate directly with all regulatory and governmental authorities in order to ensure that the PG's facilities are designed, constructed, operated and maintained in compliance with the applicable statutes, regulations, by-laws and codes.

7. GENERAL REQUIREMENTS

7.1. Point of Interconnection Considerations

The physical Point of Interconnection is determined after agreement between BC Hydro and the PG. The definition of this point will appear in the Interconnection Agreement (IA). The IA document will lay out these and other contractual details specific to the PG interconnection.

7.1.1. General Configurations and Constraints

Integration of generation projects into power systems usually falls into one of two main categories:

7.1.1.1. Substation Termination

A substation termination has the characteristics of connecting to the BCH system via a series of circuit breakers. Possible configurations are noted as follows:

a) Interconnection into a transmission bulk power substation, with (depending on the bus configuration) the transmission and generator lines

each terminated into a station containing one or more breakers.

b) Creation of a new station by looping an existing transmission line through a site.

c) Interconnection on the low-voltage side of an existing customer service transformer that was originally designed to serve loads. The high side is connected to an existing transmission line.

7.1.1.2. Transmission Line Tap

Interconnection by directly tapping a transmission line without the use of circuit breakers. This type of interconnection creates a multi-terminal line, where the generator becomes an additional current source beyond the existing sources at the line terminals. This configuration may affect BCH's ability to protect, operate, dispatch, and maintain the transmission line. The increased complexities of the control and protection schemes affect system stability and reliability. BCH determines the feasibility of multi-terminal line interconnections on a case-by-case basis.

7.1.2. Operating Voltage, Rotation, and Frequency

The BCH system operates at 60Hz with an A-B-C counterclockwise phase rotation. The standard operating voltages are as follows:

Table 1: System Voltages

Nominal Voltage (RMS, L-L)	Normal Maximum Voltages (RMS, L-L)
69	72
138	145
230	253
287	315
345	362
500	550

In some cases, lines insulated to higher than energized voltage may be used.

7.1.3. Special Configurations and Constraints

The constraints and considerations described below may substantially affect the costs of a particular integration plan, sometimes making an alternate Point of Interconnection more desirable.

7.1.4. Interconnection to Main Grid Transmission Lines

Main Grid transmission lines include all 500, 360, 287 and 230 kV lines, as defined by BCH. These circuits form the backbone of BCH's transmission system and provide the primary means of serving large geographical areas. In particular, 500 kV transmission lines connect major generating plants to load centres and interties. Modification to the 500 kV system can have considerable effect on system reliability and security. For this reason, 500 kV interconnections will be reviewed on a case-by-case basis to ensure that system integrity is not impacted.

As noted in Section 7.1.1.2, the use of three-terminal lines on the Main Grid often adversely affects system stability and security, as well as critical operation and maintenance of these lines. Lines with more than two terminals require special consideration for any interconnection and are not permitted at 500 kV. The use of three terminal lines will be evaluated individually based on the above considerations provided the following criteria is met

a) The transmission line protection meets BCH Protection Requirements (Section 9)

b) Except by specific waiver, generation requirements shall not restrain BCH from taking a transmission line out of service for prudent purposes and generator outages shall not force the line out of service, and

c) The line and all components are designed, constructed and maintained to BC Hydro's standards as outlined in Section 8.6

Otherwise, a substation, with additional breakers at the Point of Interconnection, may have to be developed. The cost of this step may make interconnection to non-Main Grid lines more appropriate for smaller projects. A Main Grid line configuration with more than three terminals is not allowed.

7.1.5. Other Considerations

7.1.5.1. Equipment

Existing electrical equipment, such as transformers, power circuit breakers, disconnect switches, arresters, and line conductors were purchased based on the duties expected in response to system additions identified in long-range plans. However, with the interconnection of a new generating resource, some equipment may become underrated and need to be replaced.

7.1.5.2. System Stability and Reliability

The BCH system has been developed with careful consideration for system stability and reliability during disturbances. The size of the PG, breaker configurations, generator characteristics, and the ability to set protective relays will affect where and how the Point of Interconnection is made. The PG may also be required to participate in special protection schemes (remedial action) such as generator shedding.

7.1.5.3. Control and Protection

BCH coordinates its protective relays and control schemes to provide for personnel safety, equipment protection, and to minimize disruption of services during disturbances. PG interconnection usually requires the addition or modification of protective relays and/or control schemes. New projects must be compatible with the existing protective relay schemes. Sometimes the addition of voltage transformers (VTs), current transformers (CTs), or transfer trip schemes also are necessary, based on the Point of Interconnection. BCH uses single-pole protective relaying on many 500 kV lines, and transfer tripping on all 500 kV and many 230 kV lines. Conventional zone protection is generally used at 138 kV and below.

7.1.5.4. Dispatching and Maintenance

BCH operates and maintains its system to provide reliable customer service while meeting the seasonal and daily peak loads even during equipment outages and disturbances. PG integration requires that the equipment at the Point of Interconnection not restrict timely outage coordination, automatic switching or equipment maintenance scheduling. Preserving reliable service to all BCH customers is essential and may require additional switchgear, equipment redundancy, or bypass capabilities at the Point of Interconnection for acceptable operation of the system.

The generator will be expected to supply up to maximum available reactive capability and/or to adjust generation levels including reducing to zero if requested by the BCH dispatcher. This will always be for security purposes.

7.1.5.5. Atmospheric and Seismic Conditions

The effects resulting from wind storms, floods, lightning, elevation, temperature extremes, and earthquakes must be considered in the design and operation of the PG. The PG is responsible for determining that the appropriate standards, codes, criteria, recommended practices, guides and prudent utility practices are met.

7.2. Safety

At the Point of Interconnection to the BCH System, an isolating disconnect switch shall be provided that physically and visibly isolates the BCH System from the PG. Safety and operating procedures for the isolating device shall be in compliance with the Worker's Compensation Board (WCB) of British Columbia and the PG's safety guidelines. Terms and conditions covering the control and operation of the disconnect device are normally covered by the operating agreements between the PG and BCH. These operating agreements are normally in the form of "Local Operating Orders" (LOOs).

The disconnect device must be:

a) Rated for the voltage and current requirements of the particular development;

b) Gang operated;

c) Operable under all weather conditions in the area;

d) Lockable in both the open and closed positions, if manually operated;

e) Interlocked with the PG's entrance breaker. (Disconnecting interlocks shall be in accordance with the latest Canadian Electrical Code requirements)

Since the disconnect device is primarily provided for safety and cannot normally interrupt load current, consideration shall be given as to the capacity, procedures to open, and the location of the device.

Surge arresters are recommended for protection of station equipment such as transformers. Surge arresters shall be located on the station side of the entrance protection CTs as shown in Figure C3 of Appendix C.

7.3. Substation Grounding

The equipment and station shall be grounded in accordance with the latest Canadian Electrical Code. It is recommended that the ground grid be designed based on the ultimate fault duty for the site. If not, the PG assumes the responsibility for upgrading when necessary to accommodate changes to the system. It is the PG's responsibility to contact BCH periodically if they have designed the ground grid to less than the ultimate fault duty specified by BCH.

The integration of generation may substantially increase fault current levels at nearby substations. Modifications to the ground grids of existing substations may be necessary to keep grid voltage rises within safe levels. Studies by BCH will determine if modifications are required and the estimated cost of such modifications.

7.4. Insulation Coordination

It will be necessary for the PG to co-ordinate its station insulation with the incoming transmission line insulation. Care should be taken where the line is constructed for future requirements to a higher voltage than the initial operating voltage.

The entire BCH transmission system is effectively grounded under normal operating conditions but 69 and 138 kV systems may become temporarily ungrounded at some locations during certain contingencies. At these locations, surge arresters rated for temporary ungrounded operation must be applied. The 230 kV and 287 kV systems are generally always grounded, but there are a few locations where ungrounding can occur, similar to the lower voltage lines indicated above. The 500 kV system is always grounded.

Voltage stresses, such as lightning or switching surges, and temporary overvoltages may affect equipment duty. Remedies depend on the equipment capability and the type and magnitude of the stress. In general, stations with equipment operated at high voltages, as well as all transformers and reactors, should be protected against

lightning and switching surges. Typically this includes station shielding against direct lightning strokes, surge arresters on all wound devices, and shielding with arresters on the incoming lines.

7.5. Station Service and Start-up Power

Power that is provided for local use at a generating plant or substation to operate lighting, heat and auxiliary equipment is the responsibility of the PG. The station service requirements of the PG, including voltage and reactive requirements, shall not impose operating restrictions on the BCH system.

Appropriate providers of station service and alternate station service are determined during the project planning process.

7.6. Isolating, Synchronizing and Blackstarting

7.6.1. Isolation

The PG shall not energize a *de-energized* BCH line unless the energization is specifically approved by BCH. If, for any reason, the BCH system is disconnected from the PG (fault conditions, line switching, etc.), the switching device connecting the PG to the system must open and not reclose until approved by BCH or as specified in the Local Operating Orders.

7.6.2. Synchronization

The PG shall synchronize its equipment to the BCH transmission system. The automatic synchronizing relay shall have frequency, voltage, slip and phase angle matching, and compensate for circuit breaker closing times. Automatic synchronization shall be supervised by a synchronizing check relay, IEEE device 25. This assures the unit is not connected to the energized power system out of synchronization.

7.6.3. Blackstarts

Blackstart is the condition when one unit of a generation project starts up under local power, in isolation from the power system. BCH may require a blackstart capability for PGs with an installed capacity that is larger than 100 MW. Things to consider for blackstart capability include the following:

- Proximity to major generation facilities (i.e., Can startup power be provided more efficiently from an existing plant?);
- Location on the transmission system (i.e., Is the PG near major load centers and far from generation?);

- Cost of on-site start-up; and
- Periodic testing to ensure personnel training and capability.

7.7. Certification of the Power Generator's Facility

A Professional Engineer, licensed in the Province of British Columbia, must declare that the PG's facility has been designed, constructed and tested in accordance with the requirements stated in this document, project specific requirements as stated by BC Hydro, and prudent utility practice.

8. PERFORMANCE REQUIREMENTS

The following performance requirements can be satisfied by various methods. It is the responsibility of the PG to provide the appropriate documentation and/or test reports to demonstrate concurrence.

8.1. Electrical Disturbances

The PG's equipment shall be designed, constructed, operated and maintained in conformance with this document, applicable laws/regulations, and standards to minimize the impact of the following:

- Electric disturbances that produce abnormal power flows,
- Overvoltages during ground faults,
- Audible noise, radio, television and telephone interference, and
- Other disturbances that might degrade the reliability of the interconnected BCH System.

8.2. Power Quality

The operation of the PG's generator(s) shall not degrade the quality of electricity in the BCH system.

8.2.1. Power Parameter Information System

BC Hydro requires a Power Parameter Information System (PPIS) to ensure proper power quality is maintained for on-line, off-line, steady and dynamic states. The PPIS is capable of high-speed sampling to capture information such as harmonics, and voltage and current levels. The information captured will allow BC Hydro and PG staff to assess the condition of electricity generating from the PG's facility.

BC Hydro will provide the system's requirements, including approved measurement devices (i.e. PML 7700) to the PG. The PG will supply, install and commission the PPIS at the PG's expense. If requested, BCH will perform these services at the PG's cost.

See Appendix D for details on the PPIS.

8.2.2. Voltage Fluctuations and Flicker

Voltage flicker is an increase or decrease in voltage over a short period of time, normally associated with fluctuating load. The characteristics of a particular flicker problem will depend on the characteristics of the load change.

The voltage flicker problem may arise during the start-up of an induction generator, motor, energization of a transformer, or other equipment as the large starting current may cause the voltage to drop considerably. The PG shall take steps to minimize flicker problems from their generator(s).

In order to prevent voltage fluctuations from causing serious disturbances to customer's equipment connected nearby on the grid, voltage fluctuation on a phase-to-phase and phase-to-ground basis shall not exceed +5% and -6% on a 60 Hz rms basis compared to the average in the immediately preceding one second period. The value, which is compared to the preceding one-second average, is the root mean squared (rms) value calculated over any ½ 60 Hz cycle.

The standards for voltage fluctuations at the point of connection of the PG's facility with BCH are as follows:

Table 2: Voltage Fluctuations

Voltage Change	Maximum Rate of Occurrence
+/-3% of normal level	once per hour
+5/-6% of normal level	once per 8-hour work shift
Exceeding +5/-6%	pre-scheduled by BCH

Voltage dips more frequent than once per hour must be limited to the "Border Line of Visibility Curve" contained in Appendix H, Permissible Voltage Dips – Borderline of Visibility Curve.

8.2.3. Voltage and Current Harmonics

Harmonics can cause telecommunication interference and thermal heating in transformers; they can disable solid state equipment and create resonant overvoltages. In order to protect equipment from damage, harmonics must be managed and mitigated. The PG's equipment shall not cause voltage and current harmonics on the BCH system that exceed the limits specified in IEEE Standard 519. Harmonic distortion is defined as the ratio of the root mean square (rms) value of the harmonic to the rms value of the fundamental voltage or current. Single frequency and total harmonic distortion measurements may be conducted at the Point of Interconnection, Generation Site, or other locations on the BCH system to determine whether the PG's equipment is the source of excessive harmonics.

8.2.4. Phase Unbalance

Unbalanced phase voltages and currents can affect protective relay coordination and cause high neutral currents and thermal overloading of transformers. In general, to protect BCH and customer equipment, the PG's contribution at the Point of Interconnection shall not cause a voltage unbalance greater than 1% or a current unbalance greater than 5%. Phase unbalance is the percent deviation of one phase from the average of all three phases. However, if the existing unbalance at the Point of Connection is shown to be already quite high, the PG's contribution may cause the unbalance to exceed the specified amount. This will be considered on a case by case basis.

8.3. Switchgear

8.3.1. General

Circuit breakers, disconnect switches, and all other current carrying equipment connected to BC Hydro's transmission system shall be capable of carrying normal and emergency load currents without damage. Only circuit breakers (CB) will be acceptable as an interrupting device, for protection initiated tripping, at PG installations.

All circuit breakers shall have an interrupting rating equal to or higher than the fault duty at the specific location as determined by BCH. The circuit breaker shall have this capability without the use of intentional time delay in clearing, fault reduction schemes, etc. Application shall be in accordance with ANSI/IEEE C37 Standards. These requirements apply to the Generation Site, the Interconnecting Substation, the Point of Interconnection as well as other locations on the BCH Transmission System. BCH will also determine an

'ultimate' fault duty for the location. If the CB supplied has a lower interrupting rating, the PG assumes the responsibility for upgrading when necessary to accommodate changes to the system and the PG is responsible for contacting BCH to ensure their equipment is suitably rated.

The circuit breaker shall be capable of performing all other required switching duties such as but not limited to: capacitive current switching, load current switching, and out-of-step switching. The circuit breaker shall perform all required duties without creating transient overvoltages that could damage BCH equipment. Switchgear on the high side of a Delta-Grounded Wye (D-YG) transformer that can interrupt faults or load must be capable of the increased recovery voltage duty involving interruptions while ungrounded. When generation is connected to the low-voltage side of a D-YG transformer, the high-voltage side may become ungrounded when remote end breakers open, resulting in high phase-to-ground voltages.

8.3.2. Circuit Breaker Operating Times

Table 3 specifies the operating times typically required of circuit breakers on the BCH Transmission System. These times apply to equipment at the Generation Site and the Point of Interconnection. System stability considerations may require faster opening times than those listed. Breaker close times are typically four to eight cycles.

Table 3: Circuit Breaker Operating Times

Nominal Voltage Class	**Rated Interrupting Time (Cycles)**
500 kV	2
287 kV – 345 kV	2
230 kV	3
115 kV – 161 kV	3
69 kV and below	5

8.4. Generators

The generators shall be designed in accordance with applicable standards and as specified below.

8.4.1. Power

The active power output should be limited to Rated Power (MVA rating times rated overexcited power factor) so that rated continuous reactive power output is available for power system emergencies. Planned operation above rated power must be negotiated with BCH.

8.4.2. Generator Modelling

The PG shall provide complete models for each component of each generating unit and the models and their associated data shall be validated in accordance with Appendix F.4.

8.4.3. Reactive Power Requirements

When operating at rated terminal voltage and within the generating unit's complete range of output power, each synchronous generator shall be able to operate continuously in a range from an over-excited power factor of 90% to an under-excited power factor of 95%.

Under all ambient conditions, each generator must be able to operate continuously at its Maximum Power Output (MPO) and at rated field current and at any terminal voltage level within plus 10% and minus 10% of rated terminal voltage.

The generator may be required to follow a specified voltage or var schedule on an hourly, daily, or seasonal basis depending on the location of the generator. BCH will specify the desired generator voltage setting or desired Mvar output level. The generator may be required to change its Mvar output or voltage reference set point from time to time depending on system conditions and the location of the generator. In most cases, especially for generators larger than 10 MVA, if the BCH system operator does not have direct control over the generator's voltage regulator via supervisory control, the PG's operator must be able to respond and implement the new Mvar output or voltage reference set point within 5 minutes.

The generator and its auxiliary equipment must be capable of operating for periods of at least 30 seconds at any generator terminal voltage level between 0.70 pu and 1.20 pu with the main circuit breaker open to allow the open circuit saturation test to be conducted.

With the generator initially operating at any point within its capability curve and at any terminal voltage level within +10% and -10% of nameplate, and without operator intervention, the generator must be able to withstand for at least

30 minutes, a system disturbance that results in the generator terminal voltage dropping to 90% of the generator's rated terminal voltage.

With the generator initially operating at any point within its capability curve and at any terminal voltage level within +10% and -10% of nameplate, and without operator intervention, the generator must be able to withstand, for at least 30 minutes, a system disturbance that results in the generator terminal voltage rising to 110% of the generator's rated terminal voltage.

If the generating unit main (step-up) transformer is equipped with an Under-Load Tap-Changer (ULTC), the ULTC must be operated in manual mode whenever the generator is on line unless the generator's automatic voltage regulator is sensing the voltage on the HV side of the generator step-up transformer. This is to ensure that, immediately following a major system disturbance resulting in abnormal system voltage levels; the generator participates to the fullest extent to restore normal system voltage levels.

8.4.4. Excitation Equipment

Synchronous generator excitation equipment shall follow industry best practice and applicable industry standards. Excitation equipment includes the exciter, automatic voltage regulator, power system stabilizer and over-excitation limiter.

The excitation system shall be a high initial response type as defined by IEEE Standard 421.4, capable of attaining 95% of the difference between the available ceiling voltage and rated load field voltage in 0.1 second or less. Ceiling voltage, defined as the maximum exciter voltage attainable under initial conditions of generator rated MVA, rated power factor, rated terminal voltage and rated speed, shall be greater than 3.0 pu. Negative ceiling voltage capability shall also be provided. The excitation system shall be capable of producing the field current required for continuous operation at generator rated MVA, rated power factor, 1.10 pu terminal voltage and rated speed ("Excitation System Rated Current"). It shall also be capable of providing 1.6 times the excitation system rated current for 30 seconds ("exciter overload current rating").

The PG shall provide a copy of all excitation system controls, limiters, and protective equipment settings to BC Hydro.

8.4.4.1. Voltage Regulator

If the generator is rated at 10MVA or greater, the generator exciter shall be equipped and operated with an Automatic Voltage Regulator (AVR) set to control the generator terminal voltage. Under steady state conditions, the AVR shall be capable of automatically maintaining the generator terminal

voltage, without hunting, to within plus or minus 0.1% of any set point within an operating range between plus 20% and minus 30% of the rated terminal voltage of the generator. This control range is for testing purposes only and is not meant to require that the generator and excitation equipment have the capability to operate for any significant length of time at these terminal voltage levels.

8.4.4.2. Excitation System Limiters

The excitation system must be equipped with limiters that are well coordinated with the generator protective relays. The limiter settings must not restrict the generator's operating range (terminal voltage and Mvar limits) to less than 100% of the continuous capability of the equipment (i.e., the limiters must not overly protect the generating unit's components at the expense of system security).

The limiters must control the exciter output to avoid unnecessary operation of the generator's protective relays in the event of any sudden abnormal system condition. In such a case, the AVR may to attempt to exceed the generator Mvar limits in its efforts to maintain the pre-set voltage reference point.

Limiters shall be of the non-windup type. The output of each limiter shall immediately return to zero upon the elimination of the cause of the overload. Limiters shall not switch the excitation system from automatic to manual voltage control.

8.4.4.3. Power System Stabilizer (PSS)

A power system stabilizer (PSS) shall be provided. The PG shall provide BCH with information on the type of PSS required for each generator. Once the generating unit equipment (i.e., generator, turbine, exciter, step-up transformer, etc) characteristics have been provided by the various suppliers, BCH will conduct studies at the PG's cost to determine the optimum PSS settings. The recommended settings will be implemented and confirmed by field tests during the commissioning of each generator.

8.4.5. Governor

Generators shall be required to have speed governors on their prime movers. Governors must be operated unrestrained to regulate system frequency and to provide added system stability.

The governor characteristics shall be set to provide a 5 percent droop characteristic, i.e. if the generator were isolated from the interconnected system

and its loading were raised from zero to 100% of its rated MW output, the generator frequency should drop by 5% (from 60 Hz to 57 Hz). The governor shall not have a deadband of more than 0.056 Hz

The performance requirements for the governor system for operation in BCH shall generally be in accordance with Section 4 of IEEE Standard 125 "IEEE Recommended Practice for Preparation of Equipment Specifications for Speed Governing of Hydraulic Turbines Intended to Drive Electric Generators" and with Section 4 of IEEE Standard 122 "IEEE Recommended Practice for Functional and Performance Characteristics of Control Systems for Steam Turbine-Generator Units." Similar performance requirements shall apply to all types of Prime Movers (including reciprocating combustion engines and gas turbines).

8.4.6. Voltage and Frequency Operation During Disturbances

Power system disturbances initiated by system events such as faults and forced equipment outages expose connected generators to oscillations in voltage and frequency. It is important that generators remain in service for dynamic (transient) oscillations that are stable and damped. Over/under voltage and over/under frequency relays are normally installed to protect the generators from extended off-nominal operation. To ensure that the PG is not tripped prematurely, the required time delays for setting these relays are presented in the 'Protection Requirements' Section 9.4 and 9.5.

8.4.6.1. Frequency

Each generator must be capable of continuous operation at 59.5 to 60.5 Hz and limited time operation for larger deviations from normal frequency. Also, when system frequency declines, loads are automatically interrupted in discrete steps, with most of the interruptions between 59.5 and 57.5 Hz. Load shedding within the BCH system attempts to stabilize the system by balancing the generation and load.

Over/under frequency relays are normally installed to protect the generators from extended off-nominal operation. It is imperative that generators remain connected to the system during frequency excursions, both to limit the amount of load shedding required and to help the system avoid a complete collapse. To ensure that the generator is not tripped prematurely, BCH will specify the minimum required time delays for setting the PG over/under frequency protection relays.

8.4.6.2. Voltage

Each generator must be capable of continuous operation at 0.90 to 1.10pu

To avoid voltage collapse in certain areas of the BCH system, undervoltage load shedding has also been implemented. The PG undervoltage relay settings must coordinate with the undervoltage load shedding program.

The nominal voltage levels available for connecting to BCH will depend on the location of the PG facility. Normal operating voltages on BCH can vary by up to +/-10% of nominal voltage levels. The normal voltage level may vary over a wider range at certain locations, and larger variations will occur during abnormal or emergency conditions.

8.4.7. Contingencies

The PG shall be responsible for determining and adequately designing and protecting its generating plant against the impacts caused by switching operations and contingencies in the BCH system. Some examples are as follows:

1. Load rejection on the PG generating plant will cause over-speed and over-voltages in the PG plant. The amount of over-speed and over-voltage will be a function of the electro-mechanical parameters of the interconnected system and the PG plant.
2. Self-excitation can occur where an islanded transmission system, left connected to the PG generating plant, represents a capacitive load in excess of the PG synchronous generator's capability to absorb it. The PG plant could be damaged by the resulting over-voltage if the plant is not quickly disconnected from the transmission system.
3. Resonance situations may occur where an islanded transmission system is left connected to the PG generating plant. This will cause unacceptably high transient over-voltages unless corrective measures are provided.
4. Reclosing of BCH lines could connect an islanded PG generating system to the BCH system when the two systems are out of synchronism. To prevent the PG generating plant from being damaged by such reclosing operations, the plant may need to be disconnected from the transmission system prior to the reclose or BCH may provide a means of preventing reclosing.
5. Acceleration of the PG generating plant during faults on nearby BCH transmission lines could cause the plant to slip out of synchronism with the BCH system. Therefore, it may be necessary to prevent this loss of synchronism by decreasing the existing fault clearing times on the nearby BCH transmission system. Alternatively, it may be necessary to disconnect the PG's generating units quickly to minimize the impact on the BCH system.

8.5. Transformers

Transformer reactances and tap settings should be coordinated with BCH to optimize the reactive power capability (lagging and leading) that can be provided to the network. Refer to IEEE Std. C57.116, *Guide for Transformers Directly Connected to Generators*. The generator continuous reactive power capability shall not be restricted by main or auxiliary equipment, control and protection, or operating procedures.

The voltage and winding connections for which the transformers are to be designed shall be provided by BCH. BCH recommends generator step-up transformers having off-load taps on the secondary (HV side) with a minimum range of 2 x 2 1/2 percent above and 2 x 2 1/2 percent below usual delivery voltage. The adjustment range necessary for each installation shall be determined in consultation with BCH.

Transformer winding arrangements which result in zero sequence current contributions from the PG transformer to faults on the BCH system are generally not acceptable for protection reasons for installations tapped into a mid-line location. For these installations, a delta connected HV winding is generally recommended. For installations that connect to a substation, wye-connected HV windings are recommended together with appropriate ground fault protection for the connecting transmission line.

The transformer shall be dimensioned to accommodate the voltage and frequency excursions associated with expected load rejection and system separation events.

8.6. Transmission Lines

The design of the line should be in accordance with sound engineering practices to ensure satisfactory operation and to avoid adverse impacts on the safety and security of the BCH system.

As a minimum requirement, the design should meet the latest version of Canadian Standards Association standard for Overhead System CAN/CSA C22 3 No. 1, which forms part of the Canadian Electrical Code Part III.

The construction and design must also meet BC Hydro's Engineering Standards for Overhead Transmission Lines if the line will be owned by BCH or the line is a tap connection as described in Section 7.1.1.2.

Design studies must be conducted to determine the actual climatic loadings at high elevations (rime icing), long water crossings (high wind exposure) and coastal areas (possible heavy glaze icing).

Unless the expected life of the installation is shorter, the design regarding wind and ice storms should be based on a 40 year return period for lines 138 kV and below.

and a 100 year return period for lines 230 kV and above. Also, outages due to conductor galloping should be negligible.

8.6.1. Conductor Size

The thermal and physical loadings the conductors must carry, and the maximum design conductor temperature, govern the type and size of the phase conductors.

Unless otherwise agreed by BCH, the operating temperature of the conductor shall be limited to 90°C under all operating conditions. The mid-span conductor-to-ground clearance should at least meet the CSA requirements when the conductor is operating at its maximum design temperature.

The conductor size should also be large enough to meet radio interference (RI) regulations. Further, care should be taken during construction to avoid any damage to the surface of the conductor that may lead to increase in RI levels.

8.6.2. Line Insulation

Table 4 provides the typical values used in BCH's system. The values may need to be increased depending on altitudes, degree of pollution, and where special icing problems exist.

Table 4: Line Insulators and Clearances

Nominal Voltage (rms, L-L)[1]	Number of insulator elements[2] in a string	Conductor to Tower Clearance
69 kV	4	0.46 m
138 kV	7	0.84 m
230 kV	12	1.38 m
287 kV	15	1.78 m

Note 1: Requirements for 360 kV and 500 kV will be supplied on a case by case basis.

Note 2: Insulator elements are utility standard porcelain or glass insulators with a height of 5 ¾" and a diameter of 10".

8.6.3. Shield Wire

The overhead shield wires should be capable of carrying the present and future fault currents. BCH will provide the existing and expected future fault currents for various types of faults at the point of interconnection when the output, equipment characteristics and location of the PG's development has been submitted.

Interconnections at operating voltages of 230 kV or greater must provide overhead shielding on transmission structures up to a distance of 500 m out from each terminating station. The objective of the shielding is to limit the rate-of-rise of the surges entering the substation. Longer shield wires may be required in some circumstances.

8.6.3.1. Single Circuit Configuration

Where the interconnection will be through one circuit, it is advisable to shield the whole line, regardless of the voltage to avoid a forced outage of the generator(s) that would otherwise occur whenever lightning strikes the line.

8.6.3.2. Multiple Circuit Configuration

Where the interconnection will be through more than one circuit, shielding will not be required at an interconnection voltage of less than 230 kV. This is due to the principle that a lightning outage will only affect one of the lines, allowing the generation to remain on line using the other line.

9. PROTECTION REQUIREMENTS

9.1. General Requirements

The PG protection must satisfy the following fundamental requirements:

9.1.1. Sensitivity and Coordination

The PG shall provide protection with adequate sensitivity to detect and clear all electrical faults on its premises, and coordinate with other BCH protection systems, considering present to ultimate fault levels. This protection is generally referred to as 'Entrance Protection'. In terms of this document coordination is defined as either:

a) Fully selective clearing - the PG's protection shall clear all faults in the PG's installation before other relaying on BCH initiates tripping for such faults;

b) Simultaneous clearing - the PG's protection shall clear all faults in the PG's installation simultaneously with the clearing of such faults by BCH protection

Alternative a) will apply for PG installations, unless protection requirements on the BCH system dictate that alternative b) must be used.

9.1.2. External Fault Detection

Additional protection shall be provided to detect transmission faults on the BCH system. This protection is generally referred to as 'Transmission Line Protection.' Required fault clearing times will be specified by BCH.

9.1.3. Equipment Rating

The PG's equipment shall be rated to carry and interrupt the fault levels that are or will be available at the PG's location - this includes the ultimate fault currents specified by BCH. The PG's equipment includes all its station and transmission facilities, including but not limited to all protection equipment forming the entrance and transmission line protection: current transformers, potential transformers, secondary cabling, dc system/battery charger, switchboard wiring and protective relays. If the equipment supplied is not designed for the ultimate fault duty, the PG assumes the responsibility for upgrading when necessary to accommodate changes to the system and the PG is responsible for contacting BCH to ensure their equipment is suitably rated.

9.1.4. Unbalance and Undervoltage

The PG's equipment may be subjected to negative sequence current due to unbalance on the BCH system. These unbalances will be of particular concern where rotating three-phase machines are present. The PG is therefore encouraged to consider the provision of negative sequence (unbalance) protection (46) to protect his equipment.

If under-frequency tripping of generator units is applied, a solid state or microprocessor-based relay should be used. The setting must co-ordinate with BCH (WSCC) requirements.

During emergencies or abnormal operating situations on the BCH system, the PG may experience undervoltage conditions. The PG is encouraged to consider the provision of timed undervoltage-tripping (27) to protect his equipment.

9.2. Entrance Protection

The PG's entrance circuit breaker shall be included in the entrance protection zone. That is, the relays shall connect to CTs on the BCH side of the circuit breaker, as shown in Figure 1.

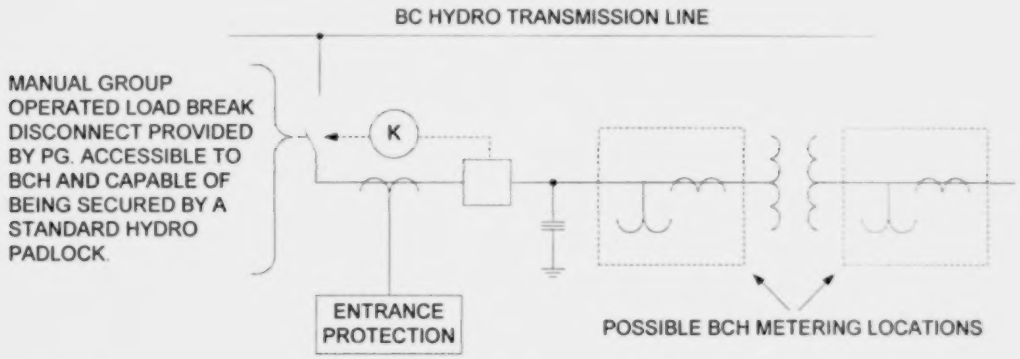

BC HYDRO TRANSMISSION LINE
MANUAL GROUP OPERATED LOAD BREAK DISCONNECT PROVIDED BY PG. ACCESSIBLE TO BCH AND CAPABLE OF BEING SECURED BY A STANDARD HYDRO PADLOCK.
K
ENTRANCE PROTECTION
POSSIBLE BCH METERING LOCATIONS

Figure 1: Entrance Protection One-Line

All BCH and PG metering equipment shall be included in the entrance protection zone or inside the PG's internal protection zones. No metering equipment shall be located on the BCH side of the entrance protection zone.

9.3. Transmission Line Protection

Since PGs will contribute to faults on the BCH system, the PG shall provide redundant equipment to clear all phase and ground faults on the utility transmission line. Where redundant or equal grade protection is provided, the protection must be physically separated and separately fused to the dc supply. In some cases, BCH will require equal grade primary and standby protection to meet this requirement. For more simple installations, redundant protection in a single scheme may be acceptable to BCH.

As well as providing protection to detect transmission line faults and prevent ungrounded energization, the PG shall provide breaker failure protection for the entrance circuit breaker.

The PG must provide a method to prevent energization of the ungrounded transmission line to the PG, as could happen if the PG's transformer has a delta connected HV winding and the line is open at the BCH terminal(s). Depending on the specific circumstances, redundant equipment may be required.

Depending on the location and method of connecting to the BCH system, communications assisted line protection may be required to provide acceptable fault clearing times.

PGs will be required to provide power quality protection, i.e. undervoltage, overvoltage, underfrequency and overfrequency protection. The setting must coordinate with BCH (WSCC) requirements.

9.3.1. Detection of Ground Faults

The method used to detect ground faults will depend on the winding configuration of the PG's transformer. Possible methods include zero sequence voltage detection (using a voltage relay, 59N, connected to the broken delta secondary connection of primary voltage instrument transformers) or zero sequence current detection (using a current relay, 51N, to measure zero sequence current flow from the PG to BCH).

9.3.2. Detection of Phase Faults

Dedicated phase fault protection shall be provided by the PG to clear isolated multi-phase faults on the BCH transmission system. Appropriate to the installation, this protection will consist of under-voltage relaying (27), directional inverse time over-current relaying (67), impedance relaying (21), or inverse time over-current relaying (51).

9.3.3. Breaker Failure Protection of PG HV Circuit Breaker

Breaker failure protection shall take one of the following forms:

a) CB auxiliary switch scheme

b) Current-based scheme

c) Remote back-up coverage via other relaying within the PG's plant

9.3.4. Prevention of Energization of Ungrounded Transmission Line

An acceptable method to prevent energization of a line that is open at the BCH terminal(s) is to send a transfer trip signal from the open BCH terminal(s) to the PG.

A sample installation of PG Transmission Line Protection is shown in Figure 2.

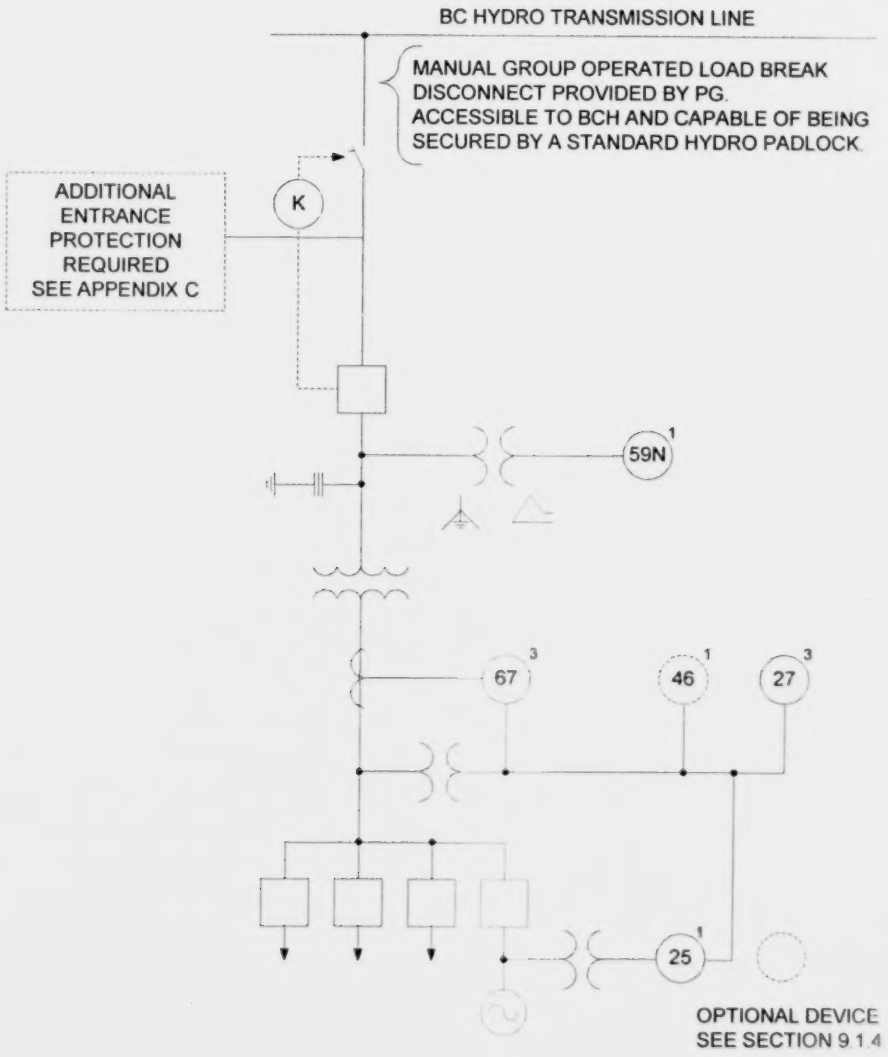

BC HYDRO TRANSMISSION LINE
MANUAL GROUP OPERATED LOAD BREAK DISCONNECT PROVIDED BY PG. ACCESSIBLE TO BCH AND CAPABLE OF BEING SECURED BY A STANDARD HYDRO PADLOCK
ADDITIONAL ENTRANCE PROTECTION REQUIRED SEE APPENDIX C
K
59N 1
67 3
46 1
27 3
25 1
OPTIONAL DEVICE SEE SECTION 9.1.4

Figure 2: Sample Installation of Minimum PG Transmission Line Protection

9.4. Off-Nominal Voltage Operation

Generating units connected to the BCH system should stay on-line without tripping for as long as possible during off-nominal voltage excursions to contribute to the restoration of normal system voltage. During a severe system disturbance, the PG generators must not disconnect before all BCH over-/under-voltage tripping schemes

take effect. The over-/under-voltage protective relay settings indicated Table "Off-Nominal Voltage Minimum Performance" are expressed in per unit of "normal terminal voltage". "Normal terminal voltage" is defined as the terminal voltage at which the generator would normally operate when delivering its Maximum Power Output (MPO) and the voltage at the interconnection point is at its nominal value. The nominal interconnection voltage is defined as the most likely operating voltage during peak load conditions under normal system conditions. The nominal interconnection voltage will be specified by BCH. Voltage relays must have a dropout time no greater than 2 cycles

Table 5: Off-Nominal Voltage Minimum Performance

Overvoltage	Undervoltage	Minimum Delay
<1.10 pu	>0.90 pu	Continuous
-	<0.90 pu	10.0 seconds
>1.10 pu	-	5.0 seconds
>1.20 pu	<0.80 pu	2.0 seconds
>1.25 pu	<0.75 pu	0.8 seconds
>1.30 pu	-	0 seconds

9.5. Off-Nominal Frequency Operation

The off-nominal frequency performance requirement contributes to the restoration of normal system frequency during a severe system disturbance. During off-nominal frequency excursions, generating units that are not susceptible to damage for the frequency ranges listed in Table 6 (e.g. typical hydro units), must remain on-line beyond the listed minimum requirements. Those units susceptible to damage will follow the minimum criteria in Table 6.

Table 6: Off-Nominal Frequency Minimum Performance

Underfrequency Limit	Overfrequency Limit	Minimum Time
60.0-59.5 Hz	60.0-60.5 Hz	Continuous
59.4-58.5 Hz	60.6-61.5 Hz	3 minutes
58.4-57.9 Hz	61.6-61.7 Hz	30 seconds
57.8-57.4 Hz		7.5 seconds
57.3-56.9 Hz		45 cycles
56.8-56.5 Hz		7.2 cycles
Less than 56.4 Hz	Greater than 61.7 Hz	0 cycles

Off-nominal frequency requirements are described in detail in WSCC's document entitled, "WSCC Coordinated Off-Nominal Frequency Load Shedding and Restoration Plan."

Generators that participate in a 'Local Island' condition as described in Section 11.5 may have specific off-nominal frequency requirements to prevent power quality problems. In this instance, BC Hydro will advise of the off-nominal frequency performance criteria prior to unit operation.

Frequency relays must have a dropout time no greater than 2 cycles and shall be solid state or microprocessor technology. Relays with inverse time vs. frequency operating characteristics are not acceptable.

9.6. Batteries / Chargers / DC Supplies

PGs are to ensure that the continuous DC supply voltage rating of any relay or its associated power supply is not exceeded due to sustained overvoltages on the DC supply bus. Common examples of conditions resulting in high, sustained overvoltages are:

a) Battery chargers at the equalize setting;

b) Battery chargers connected to the DC supply bus without the station batteries (not a recommended practice);

c) Battery chargers set in the constant current charging mode.

If there is any possibility that the DC rating of a relay will be exceeded, then a passive voltage regulator of suitable rating shall be applied to each relay to limit the DC voltage to within the relay's DC rating.

Dual station batteries are not required for power protection and control equipment. A single DC supply is acceptable.

DC system requirements for PGs are as follows:

a) Protection systems that are intended to back each other up must be supplied from DC circuits, which are physically separated and separately protected. Also, power circuit breaker control circuits must be supplied from dedicated and independently protected DC circuits.

b) One undervoltage relay (set at least 5 V DC above the minimum acceptable voltage to operate the circuit breaker and associated protection and control circuitry) will be provided. The setting shall be adjustable in case the DC requirements change, for example if equipment is added or replaced at a later date. Operation of this relay is to shut down the generator and open the HV circuit breaker to disconnect the PG from the BCH when the battery voltage dips to an unacceptably low level. A time delay is recommended for this trip initiation to override temporary voltage dips. This time delay shall not exceed 1 minute. This undervoltage tripping function is not required if the PG's generating facility is manned 24 hours a day.

c) One undervoltage relay, with time delay, to provide an alarm for battery charger failure or loss of ac supply. The voltage setting and time delay shall be coordinated with the undervoltage tripping function described above.

10. CONTROL AND TELECOMMUNICATIONS REQUIREMENTS

10.1. General

As a result of the connection of a PG to the BCH system, control and telecommunications facilities, including those related to protective relaying, may be required at the PG premises and within the BCH system for safe and efficient operation of the power system and for the safety of personnel. This may include the upgrade of other BCH facilities.

All facilities and equipment defined in the following sub-sections must meet BCH approval to ensure that applicable standards and other considerations, such as functionality, proven reliability, and the availability of maintenance spares, are met. In some cases specific equipment may be defined in order to ensure compatibility

with existing equipment such as Supervisory Control and Data Acquisition (SCADA) and other data monitoring master systems located at control centres and at monitoring location.

BCH reserves the right to modify its control and telecommunications requirements when detailed information becomes available or due to changes in previously submitted information.

All costs associated with the installation, maintenance and continued support for communications access are the responsibility of the PG.

10.2. Telecommunications Assisted Protection Facilities

Telecommunications assisted protection facilities may be required for power system protection functions at the PG's premises and between other BCH locations affected by the PG connection. Facilities may include:

a) Specialized high-speed teleprotection signals for transmission line protection and to maintain power system stability;

b) Specialized high speed transfer-trip teleprotection signals for functions such as transformer protection, reactor protection, over-voltage protection, circuit overload protection, breaker failure protection and the initiation of generator shedding;

c) Telecommunications media for the protection facilities, and for remote access to electronic relays, event recorders and fault recorders (used for the analysis of power system disturbances); and

d) Suitable battery and charger systems for the above.

10.3. Operations Control and Telecommunications Facilities

Facilities reporting to BCH's System Control Centre (SCC) and/or regional Area Control Centres (ACC), and its backup control centre, may be required at the PG's premises for the real-time operation of the power system within acceptable parameter limits. Facilities may include:

a) Digital and/or analog telemetering equipment.

b) Remote control and status/alarm reporting equipment, which may be used for the dispatching of power and satisfying WSCC contractual obligations, as well as for Automatic Generation Control (AGC) and generation shedding set-up for very large plants;

c) Voice telecommunications for operating. *

d) Data telecommunications for access to remote control and telemetry equipment

e) Telecommunications media for the above; and

f) Suitable battery/charger systems for the above.

Note: Items a) and b) above are often combined in one or more SCADA Remote Terminal Units (RTUs).

* - In some cases, a single analog business telephone dial-up line may be used to interrogate the Main Revenue Meter, Backup Revenue Meter, PPIS equipment, RTU(s) and provide telephone service. This is achieved by sharing a central line using a balanced telephone line-sharing device.

10.4. Telecommunications Media

Telecommunications media alternatives between the PG and BCH, and within BCH, may include dedicated or leased metallic wire line circuits, powerline carrier, microwave radio, fibre optics, UHF/VHF radio and satellite. When two-way telecommunications media is required, full duplex (4 wire or equivalent) circuits will generally be used (except for standard voice telephone circuits on wire line, where 2 wire circuits are used).

Whenever metallic pairs are used, appropriate telecommunications entrance protection must be provided since the station ground potential can rise to hazardous levels above remote ground potential during a power system fault. Telecommunications entrance protection provides safety to personnel, prevents damage to equipment, and allows continuous use of the telecommunications media and the attached equipment during and after power system faults. This equipment must be designed to meet public carrier and BC Hydro safety and protective requirements.

Whenever powerline carrier facilities are used, appropriate carrier accessories are required. These include wavetraps, line matching units and carrier coupling devices (often CVTs with carrier accessories) both at the PG's premises and at the BC Hydro station having the other carrier terminal. In cases where a PG taps into a circuit which has power line carrier operating on it, a wavetrap will be required at the tap point on phase/s which the carrier signal may be attenuated. In some cases specialized carrier bypass facilities may be required.

11. SYSTEM OPERATING REQUIREMENTS

11.1. Generating Reserves

BC Hydro is required to carry its own generation reserves according to requirements

specified in the WSCC Minimum Operating Reliability Criteria. These include regulating reserves, contingency spinning reserves and contingency non-spinning reserves. Reserves are the obligation of the PG Operator or the purchasing agent (with respect to the generation output may assume the obligation.) Reserves may be provided by the PG, some other generator via contract, or by purchasing the reserves from a separate entity. A portion of those reserves must be maintained as spinning reserves.

11.2. Generation Dispatching

BCH's Area Control Centres (ACCs) will be the main contact for all entities with generation connected to BCH. Installations with large generating capacities may involve BCH's System Control Centre (SCC). For non-integrated areas, contacts will be as designated by BCH.

Generating schedules shall be provided to or by BCH depending on the PGs contract with the purchasing agent. The detail of the schedule shall be agreed upon with BCH's ACC or SCC. BCH dispatchers may request real time changes as necessary to maintain system security. The PG will have final responsibility for the plant.

If the PG's generation is dispatched by BCH, the PG must either provide full supervisory control facilities for each generator from a BCH control centre, or provide 24 hour telephone access to a continuously manned PG control centre via a dedicated telephone line. Within an agreed time, the manned PG control centre (or remote control) must be able to:

a) Start-up, synchronize and fully load the PG's available generators,

b) Change the output of any of the PG's on-line generators and

c) Change the mode of operation of any of the PG's generators (i.e., from synchronous condenser mode to generation mode).

11.3. Remote Synchronization

The ability to remotely synchronize the PG's generator to the BCH system may be required in the case where the PG's generators are operated remotely by BC Hydro's Area Control Centre's (ACC). Synchronization will normally be accomplished using the generator unit breakers.

11.4. Generation Shedding

Each generator or group of generators greater than or equal to 10 MW is required to

provide generation shedding equivalent to the amount of Wholesale Transmission Service (WTS) requested. For generators or group of generators greater than or equal to 100 MW, a Remedial Action Scheme for shedding of the generation equivalent to the amount of WTS is required. For generators or a group of generators less than 100 MW, the equivalent Generation Shedding may be provided by some other generator via contract, or by purchasing the reserves from a separate entity, as long as the total amount of Generation Shedding is greater than or equal to the sum of both parties' transmission service.

11.5. Generation Islanding

Islanding describes a condition where the power system splits into isolated load and generation groups, usually when breakers operate for fault clearing or system stability remedial action. Generally, the 'islanded groups' do not have a stable load to generation resource balance. However, it is possible that, under unique situations, generator controls can establish a new equilibrium in an islanded group.

BC Hydro does not generally allow islanding conditions to exist except for a controlled (temporary, area-wide) grid separation.

Relaying that responds to frequency and voltage fluctuation will trip the generator for the large voltage and frequency deviations that would tend to occur during an island condition.

In the case where a PG remains connected because of a balanced load situation, the generation in the affected in the local island must be disconnected prior to synchronizing to the main BCH system.

11.6. Ancillary Services

Beyond the basic production and delivery of electrical energy, successful operation of generators, loads, and the transmission system may involve ancillary services. Some of these services include scheduling, control and dispatch, reactive support from generators, load regulation, and operating reserves. Ancillary services are provided by contractual agreement with BC Hydro.

For large generating sources a high level of dispatchability may be mandatory to provide the BCH with the ancillary services needed to support the provision of Wholesale Transmission Services (WTS). In certain cases, smaller generating plants may be required to be dispatchable due to local considerations.

If the PG has agreed to, or is required to, provide ancillary services, the requirements for providing full remote or 24 hour manned generation control must be met as described above. The PG's generators will need to be connected to the BCH's automatic generation control (AGC) system to permit the plant output to be automatically controlled based on system frequency, time error, BCH load, intertie flows, etc.

11.7. Other Requirements

Other requirements such as reserve obligations, coordination during restoration, synchronizing requirements and other technical issues will be determined in negotiations or consultations between the PG and BCH as required.

12. OPERATING DATA REQUIREMENTS

12.1. Telemetering

BC Hydro may require telemetering equipment for readings such as MW, Mvar, MWh, and Volts. Some or all of this data may need to be supplied continuously or via historical dial-up to BCH's ACC or SCC. The specific requirements depend on the size of the plant, location strength of system at the Point of Interconnection, other generation in the area, etc. Telemetry information guidelines are as follows:

Table 7: Generator Operating Telemetry Summary

PLANT RATING	LARGEST GENERATOR RATING IN PLANT	DATA	DESCRIPTION
<10 MVA	< 10 MVA	MW, Mvar, MWh, kV, and unit status	• Report by exception using a Dial-up IED with 2-minute update interrogation on demand • IED with DNP 3.0 protocol • Non-dedicated Telus analog business line
> 10 MVA	< 10 MVA	MW, Mvar, MWh, kV, and unit status	• Real-time report by exception using an IED with DNP 3.0 protocol • Dedicated (always on) communication, i.e., Telus lease, PLC, fibre optic, microwave, etc.
> 10 MVA	> 10 MVA	MW, Mvar, MWh, kV, unit status, PSS status, AVR status, and tap changer position	• Real-time report by exception using an IED with DNP 3.0 protocol • Dedicated (always on) communication, i.e., Telus lease, PLC, fibre optic, microwave, etc.

Notes:

a) IEDs (Intelligent Electronic Devices) may be an RTU (Remote Terminal Unit), digital meter or digital relay.

b) The IED must be capable of providing all required data to BC Hydro's System Control Centre (SCC) and/or Area Control Centre (ACC) at a one second polling frequency.

c) Large plants may need to supply telemetry to SCC and require L&G8979 protocol. Telemetry connections to SCC will be reviewed on a case by case basis.

12.2. Revenue Metering

BC Hydro will supply both the main and backup revenue metering materials. The PG will be responsible for the cost associated with the main metering materials, while BCH will be responsible for the backup meter. The details on the distribution of responsibility can be found in Appendix E.

13. COMMISSIONING REQUIREMENTS

13.1. General

The PG has full responsibility for the inspection, testing, and calibration of its equipment, up to the Point of Interconnection, consistent with the Interconnection Agreement. Commissioning must be performed by competent personnel.

The PG shall comply with the various levels of Declarations of Compatibility defined in Appendix G prior to loading, synchronizing and operating. These declarations refer to key aspects where BCH must be confident of the correct operation, setting, calibration and/or installation of equipment. This may include, but is not limited to, generator performance, protective relaying, telecommunications, revenue metering, and shall confirm the compatibility of the PG's equipment and controls with BC Hydro's systems where applicable.

Commissioning tests shall confirm the safe, reliable and effective operation of all equipment in the PG's facility under normal and abnormal conditions.

A BC Hydro Field Coordinator will be assigned to the installation. To assure compatibility, BCH personnel may:

a) Witness any part of the commissioning test

b) Request additional testing

c) Conduct their own testing

Deficiencies identified during commissioning must be corrected before the interconnection is approved for operation. A copy of the commissioning reports signed and sealed by the Engineer of Record for the testing shall be submitted to BCH upon request.

13.2. Generator

As applicable, commissioning of generating units shall include, but not be limited to, the tests required by WSCC's *Testing of Synchronous Unit Reactive Limits and Dynamic Testing/Model Validation*, dated March 1997. See Appendix F.4 for more details.

The results of the generating unit testing and model validation must be provided to BCH for review and content approval before the PG will be permitted to connect their generating units to the BCH system for any purpose other than commissioning and testing.

The Western Systems Control Council (WSCC) or other reliability authority may require that some or all generating units be similarly re-tested and their models

validated periodically. All costs associated with these generating unit tests and model validation shall be borne by the PG.

Before the generating unit will be permitted to re-enter service following any generating unit equipment replacement or modification or any control system setting change:

a) The relevant WSCC-requested generating unit tests must be repeated at the PGs costs.

b) The associated models must be updated and validated against the test results.

c) The tests and model validation studies must be reviewed and approved by BCH.

13.3. Protection Equipment

Commissioning of protection equipment shall include but not be limited to:

a) Ratio, phase and polarity testing of current transformers and potential transformers.

b) Calibration checks of each protective relay by injecting the appropriate AC quantities.

c) Functional testing of the protective relays to circuit breakers and telecommunications equipment. Testing shall include minimum operating point verification for relays.

d) Load tests of protective relays immediately after initial energization.

The settings applied to selected relays will be as determined or reviewed by BCH.

13.4. Telecommunications Equipment

Functional end-to-end testing of telemetry, protection, alarms, voice, etc equipment is required.

13.5. Operating, Measurement and Control Systems

Synchronization, governor, excitation, voltage regulator, power system stablizer systems among other control schemes shall be proven.

The ratio, phase and polarity of non-protection instrument transformers shall also be tested.

Revenue metering must be tested in accordance with Measurement Canada and BC Hydro requirements.

BC Hydro may request to witness the commissioning of the Power Parameter Information System (PPIS). Commissioning involves download and testing of the device configuration, check of instrument transform connections, UPS function test, and confirmation of dial-up connection and download of data.

13.6. Apparatus

Commissioning of station apparatus equipment shall be performed in accordance with the Canadian Electrical Association's "Commissioning Guide for Electric Apparatus" or equivalent. Commissioning shall include but not be limited to:

a) Power factor test of high voltage equipment at 10 kV to ensure insulation adequacy.

b) Timing and resistance test of main and/or generator circuit breaker(s).

c) Integrity checks of auxiliary switches.

d) Continuity checks on control, power and protection cabling to equipment.

14. MAINTENANCE REQUIREMENTS

14.1. General

The PG has full responsibility for the maintenance of its equipment, up to the Point of Interconnection, consistent with the Interconnection Agreement. Maintenance must be performed by competent personnel.

Equipment used to control, generate, protect, and transmit electricity to BC Hydro shall be maintained such that the reliability of BC Hydro's system is not adversely affected. BCH reserves the right to inspect and test the equipment given reasonable notice. The PG must perform necessary maintenance requested by BCH within a reasonable period.

14.2. Scheduled Outages

Planned outages for maintenance on PG equipment shall be coordinated with BC Hydro's Area or System Control Centres. Planned outages should not impair the safe and reliable operation of BC Hydro's system where at all possible.

14.3. Preventive Maintenance

The PG shall provide a plan to BCH demonstrating how a preventive maintenance program for the electrical equipment will occur. Maintenance shall be based on time or on other factors, including performance levels or reliability, following the

manufacturers' recommendations and/or accepted electric utility preventive maintenance practices.

14.4. Protection and Telecommunications Equipment

Periodic maintenance of protection equipment shall include but not be limited to calibration testing of all protective relays and function testing to circuit breakers and telecommunications equipment at intervals of not more than 2 years.

Telecommunications equipment shall be tested every 2 years.

Facilities to provide isolation from current transformers, potential transformers and trip buses and to allow AC injection tests should be provided.

15. REGULATORY AND RELIABILITY REQUIREMENTS

All entities connected to the BCH system must comply with all existing and future regulatory and reliability requirements imposed by various authorities, such as the British Columbia Utilities Commission (BCUC), and the Western Systems Coordinating Council (WSCC).

The authorities having jurisdiction over Power Generators connected to the BC Hydro system may change from time to time and the regulatory and reliability requirements may change from time to time. It is the responsibility of each PG to ensure it complies with current regulatory and reliability requirements. Any cost associated to comply with these authourities is the responsibility of the Power Generator.

15.1. WSCC Reliability Requirements

To ensure the safe and reliable operation of the western interconnected system, the Western Systems Coordinating Council (WSCC) provides reliability guidelines to which all PGs connected to BCH must adhere.

All entities connecting to the BCH system will be required to formally agree to participate in the WSCC's Reliability Management System (RMS). PGs operating generators connected to the BCH system will be required to enter into a "Generator/Transmission Operator RMS Agreement", a model of which appears in Appendix B of the WSCC RMS document entitled, "RMS Agreement to be entered into between the WSCC and non-FERC-jurisdictional Transmission Operators within the WSCC (includes the Generator Agreement)."

A DEFINITIONS

Area Control Centre (ACC) – Each ACC is responsible for the control and operation of an exclusive area of responsibility. BCH has four ACCs controlling four sections of the BCH grid system.

BCH System – Encompasses the transmission lines and stations operated by BC Hydro.

British Columbia Utilities Commission (BCUC) – The BCUC is an independent provincial agency set up to regulate energy utilities in the province which distribute and sell electricity and gas.

Generation Site – The geographical location of the Power Generator(s) equipment. This may be near or far from the Point of Interconnection.

Interconnection Agreement (IA) – A legal document stating the contractual obligations between the PG and BCH. The document covers, but is not limited to, issues relating to facility ownership, operation, dispute mechanisms, and technical requirements. The Interconnection Requirements are incorporated in the IA.

Island – A portion of the BCH system which has become isolated due to the tripping of transmission system elements, often a single line, that is isolated from the main system and energized by a local generator.

Main Grid – BC Hydro's transmission facilities operated at 500, 360, 287 and 230 kV.

Maximum Power Output (MPO) – This is the maximum possible output from the generator under ideal conditions. For hydro units this is usually at maximum head with the wicket gates fully open.

Point of Interconnection (POI) – The physical location on the power system of the change of ownership between BCH and the PG. This may be at a different location than the Generation Site and is specified in the Interconnection Agreement.

Power Generator (PG) – A resource to produce electricity that is connected and synchronized to the BCH system. The Power Generator may consume all or some of the generated electricity on site or it may sell the generated electricity.

Rated Field Current – This is the field current required to produce rated terminal voltage at the generator's rated MVA and (over-excited) power factor.

Rated Power – The generator MVA multiplied by the over-excited power factor.

System Control Centre (SCC) – SCC dispatches generation and performs major system operating functions.

Transmission – Lines operating at voltages above 35 kV.

Western Systems Coordinating Council (WSCC) – Provides regional electric service reliability through: development of planning and operating reliability criteria and policies; the monitoring of compliance with these criteria and policies; the facilitation of a regional transmission planning process; and, the coordination of system operation through security centers. The territory of operation includes the western part of the continental United States, Canada, and Mexico.

B REFERENCES

ANSI C84.1 – Voltage Ratings for Electric Power Systems and Equipment (60 Hz)

CSA C22.1, C22.2 and C22.3 – Canadian Electric Code Parts I, II & III.

IEEE Standards (www.ieee.org)

IEEE Std. C37.1 – Standard Definition, Specification and Analysis of Systems Used for Supervisory Control, Data Acquisition and Automatic Control.

IEEE Std. C37.2 – Standard Electrical Power System Device Function Numbers

IEEE Std. C37.122 –Standard Gas Insulated Substations.

IEEE Std. C57.116 – Guide for Transformers Directly Connected to Generators

IEEE Std 80 – Guide for Safety in AC Substation Grounding

IEEE Std 81 – Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System

IEEE Std 100 – The New IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI).

IEED Std. 122 –Recommended Practice for Functional and Performance Characteristics of Control Systems for Steam Turbine-Generator Units.

IEEE Std. 125 – Recommended Practice for Preparation of Equipment Specifications for Speed Governing of Hydraulic Turbines Intended to Drive Electric Generators

IEEE Std 421-1 – IIEE Standard Definitions for Excitation Systems for Synchronous Machines

IEEE Std 421-2 – Guide for the Identification, Testing and Evaluation of the Dynamic Performance of Excitation Control Systems

IEEE Std. 421-4 – Guide for the Preparation of Excitation System Specifications

IEEE Std 519 – IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems

IEEE Std 525 – IEEE Guide for the Design and Installation of Cable Systems in Substations.

IEEE Std 605 – Guide for Design of Substation Rigid-Bus Structures

IEEE Std 979 – IEEE Guide for Substation Fire Protection.

IEEE Std 1109 – Guide for the Interconnection of User-Owned Substations of Electric Utilities

IEEE Std 1127 – Guide for the Design, Construction and Operation of Safe and Reliable Substations for Environmental Acceptance.

WSCC Guidelines (www.wscc.com)

WSCC Coordinated Off-Nominal Frequency Load Shedding and Restoration Plan

WSCC Undervoltage Load Shedding Guidelines

WSCC Generator Test Guide

WSCC RMS Agreement to be entered into between the WSCC and non-FERC-jurisdictional Transmission Operators within the WSCC – Canadian Version

WSCC Reliability Criteria

C PROTECTION - EXAMPLE INSTALLATIONS

C.1 General

Section C.2 illustrates by example the entrance protection requirements for two specific sample installations. In no way are the installations meant to be an all encompassing set which covers all PG installations. Further, the examples do not include "Transmission Line Protection" which must be applied. Refer to Section 9.3 for information on this requirement.

The connection to the BCH system will generally take one of two forms as shown in Figures C1 and C2.

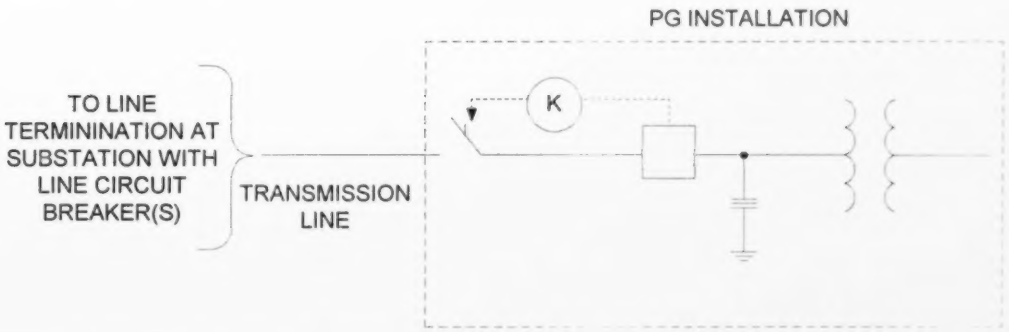


Figure C1 - Radial Line

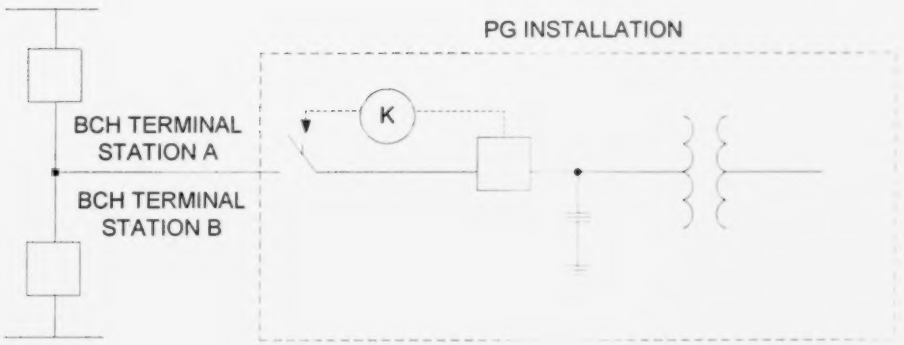


Figure C2 - Tap into Transmission Line

In the case of a PG tapped into a transmission line as shown in Figure C2, the PG shall coordinate on a radial basis with either line terminal. This means that the PG's entrance protection shall coordinate with terminal A relaying when the terminal B breaker is open, and coordinate with terminal B relaying when the terminal A breaker is open.

There may be particular protection requirements for each of the two types of connections shown but invariably the type and form of protection at the BCH source station(s) will have a more significant impact than the supply connection.

In addition to the protection specified in the examples which follow, extra relays may be installed at the PG's option for improved sensitivity. Optional relays include overload (40), phase imbalance (46) and gas detector (63).

C.2 Entrance Protection - Example Installations

The relay types, ranges and time characteristics will be subject to BCH approval.

Example 1

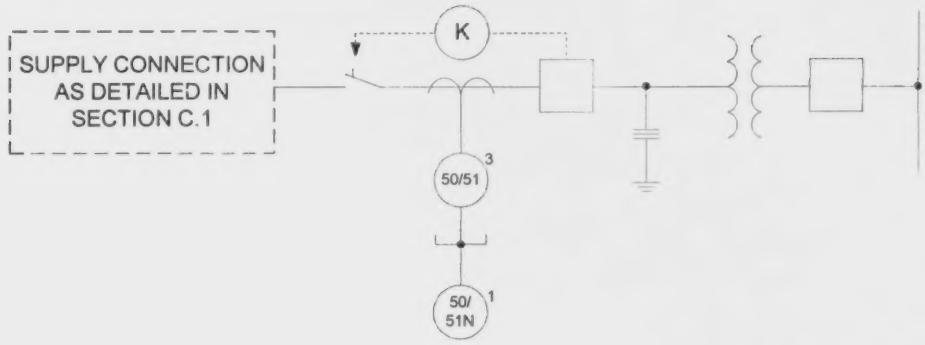


Figure C3 - Protective Relaying, Example 1

Minimum relay requirements for this application are three phase overcurrent relays (50/51) and one ground overcurrent relay (50/51N) of the inverse or very inverse type with instantaneous trip elements, selected and set such that they will co-ordinate with the respective phase and ground overcurrent relays at the BCH sources.

In fault current ranges where fully selective coordination is not possible, the PG's relays must trip their associated circuit breaker at the same time as BCH's line terminal trips, to assure that the PG has been tripped off prior to automatic or supervisory reclosing of the line terminals.

Figure C4 depicts the coordination curves for this example installation.

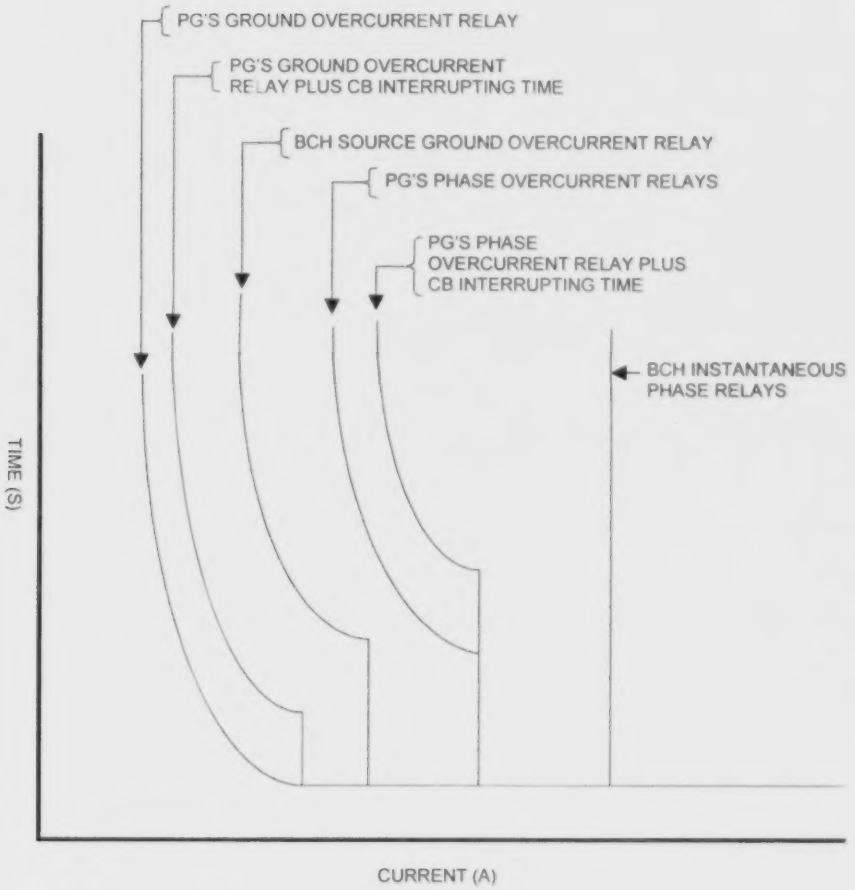

PG'S GROUND OVERCURRENT RELAY
PG'S GROUND OVERCURRENT RELAY PLUS CB INTERRUPTING TIME
BCH SOURCE GROUND OVERCURRENT RELAY
PG'S PHASE OVERCURRENT RELAYS
PG'S PHASE OVERCURRENT RELAY PLUS CB INTERRUPTING TIME
BCH INSTANTANEOUS PHASE RELAYS
TIME (S)
CURRENT (A)

Figure C4 - Coordination Curves, Example 1

In order to achieve coordination, settings of the PG's instantaneous phase elements may, in certain cases, have to be so low that some coordination within the PG's premises may need to be sacrificed. If the degree of misco-ordination is too great, another approach may be applicable – refer to Example 2.

Example 2

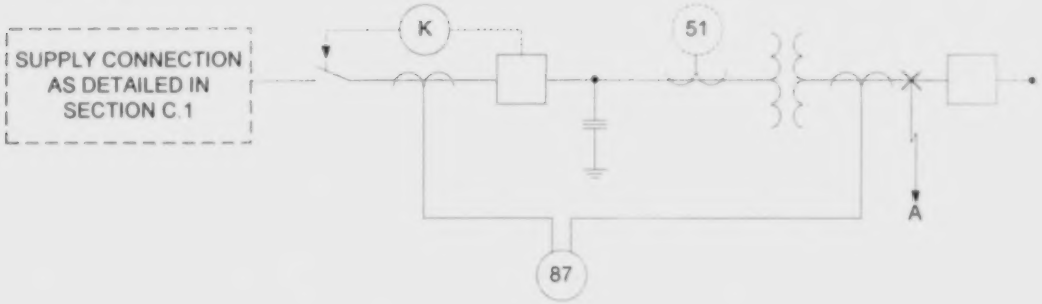


Figure C5 - Protective Relaying, Example 2

The minimum relay requirement for this application consists of a transformer differential relay (87). In some instances BCH may also require the optional phase overcurrent relays (51) if the utility protection can detect faults on the secondary of the entrance transformer outside the differential zone - for example, a fault at location A.

D POWER PARAMETER INFORMATION SYSTEM

D.1 General Description

The Power Parameter Information System (PPIS) monitors and records individual power-line electrical parameters (kW, kvar, kV, kVA, PF, Hz, Harmonics, Transients, Min, Max, Events and etc.) The PPIS is usually installed at the Generator Site facility but another location suitable location may be selected with agreement between the PG and BCH. Supplied and installed by PG including hardware and software program, the on-line PPIS checks power system performance and provides technical information on electrical system operation in steady and dynamic states and during power outages. This information is available to both the PG and BC Hydro technical personnel.

D.2 Power Parameter Information System Requirements

The PPIS consists of a multi-profile power meter with local display unit; protection grade voltage transformers (VT, 120V secondary) and current transformers (CT, 5A secondary); FT-1 type test blocks or alternatively, revenue type blocks; analogue business telephone line with facility entrance protection; telephone modem (set at 9600 Baud); RS232 modem cable; and an un-interruptible power supply (UPS). These components are interconnected to provide power parameter information via either the local display unit or remote access with application software acceptable by BC Hydro.

The full three-phase VTs and CTs (including optional transformer neutral CT when required) installed at the Generator Site are the input source to the power meter. The VT and CT test blocks are for testing and maintenance purposes, while the telephone modem provides remote access, and the UPS ensures minimum of 4 hours of PPIS operation during power outage. The PPIS system is preferably installed indoors in the control cubicle are with front mounted local display unit, but may be located within the backup revenue metering cabinet if necessary.

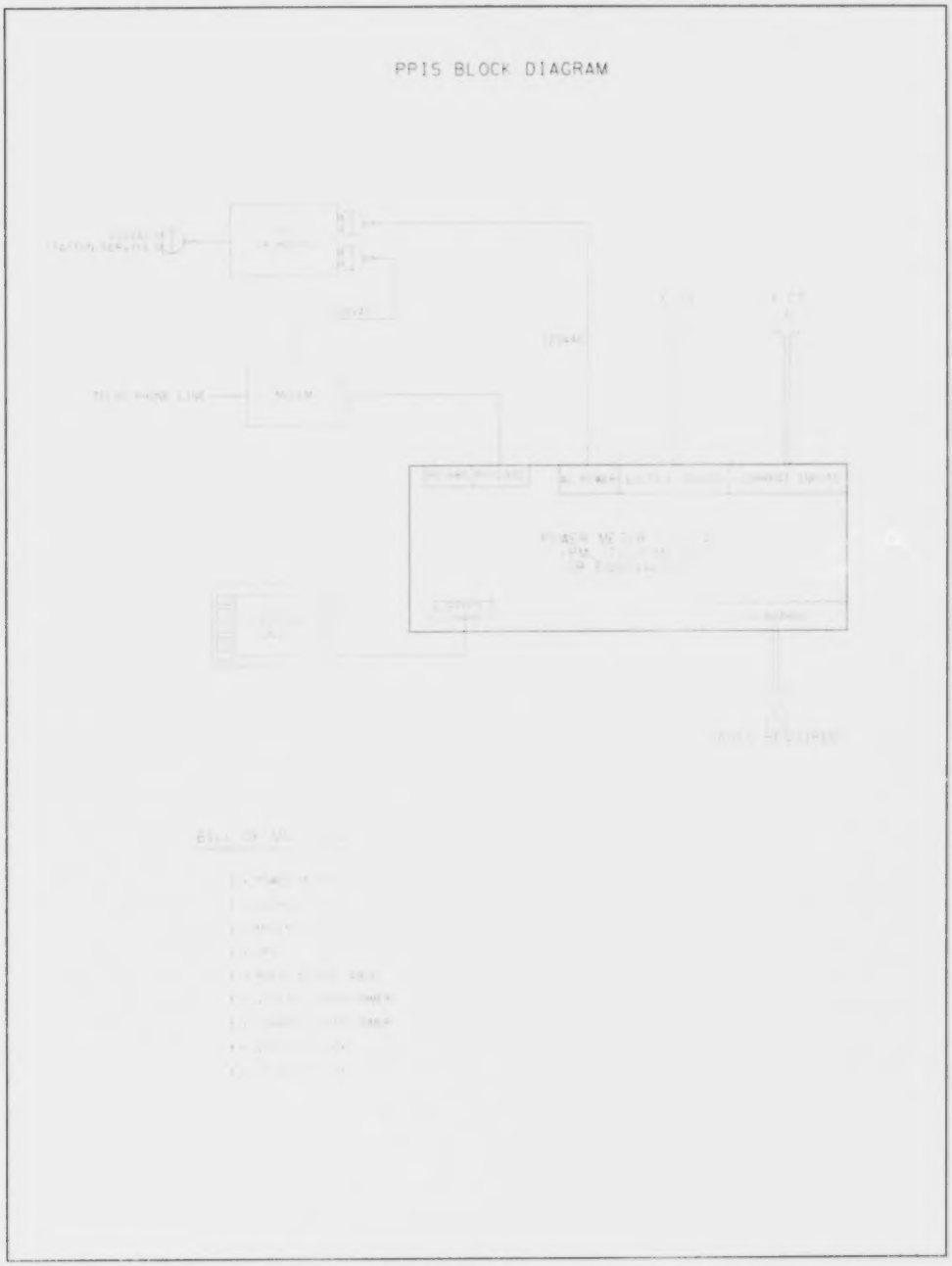
D.3 Commissioning

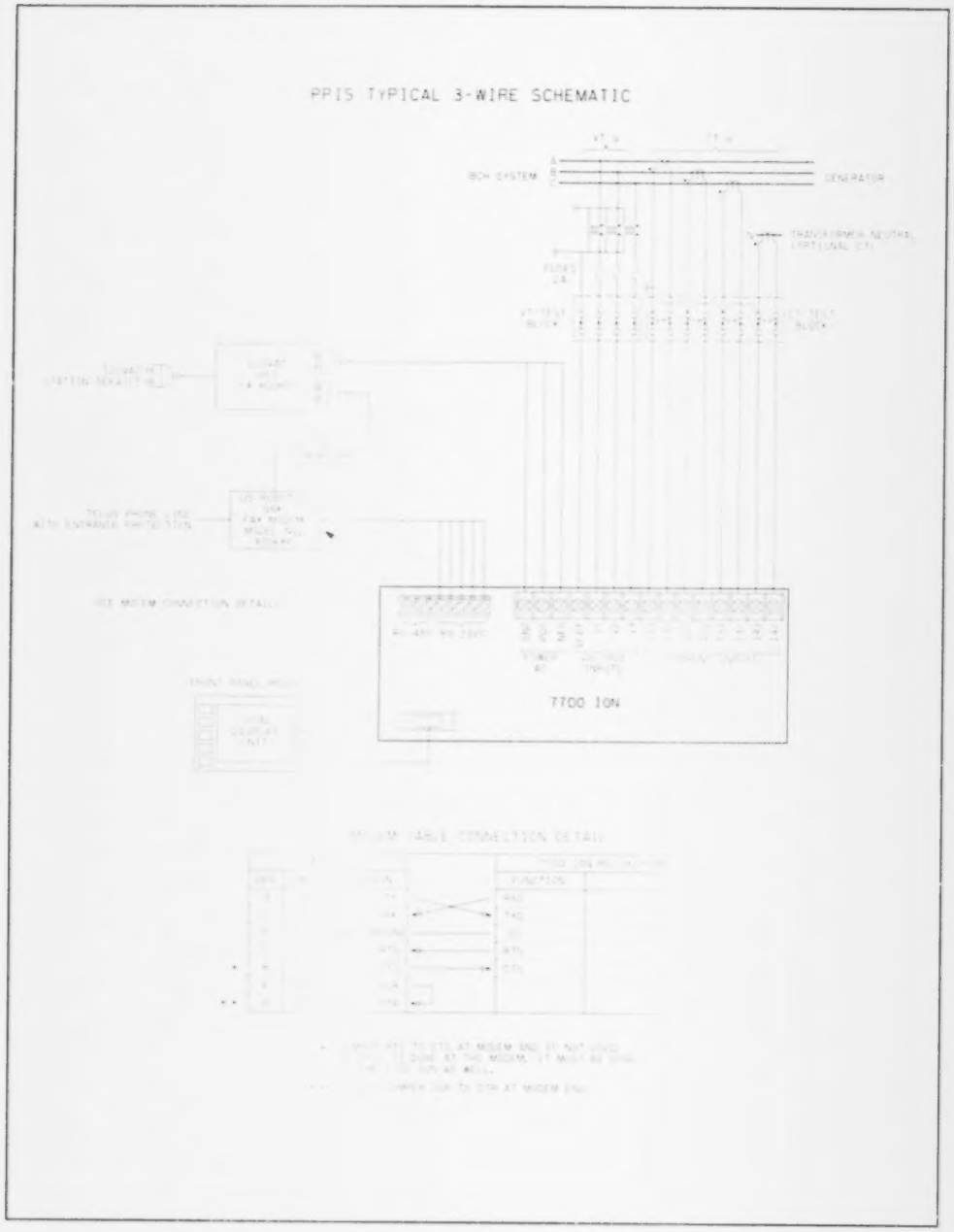
The PPIS system shall be commissioned by the PG prior to generator operation. It shall be checked, tested and recorded for correct wiring, phasing, voltage and current levels, as well as functional tests for local and remote access by BC Hydro. PPIS configuration, programming, settings and recordings tasks are to be done by BC Hydro technical personnel.

D.4 Operation and Maintenance

BC Hydro will connect to PPIS on-line and/or periodic download the captured information. This system requires very low maintenance, however BC Hydro requires access to the system on site for inspection, testing and calibration purposes.

D.5 PPIS Reference Drawings




PPIS TYPICAL 3-WIRE SCHEMATIC
7700 ION

E REVENUE METERING REQUIREMENTS

E.1 Overview

Revenue metering includes a main meter and a backup meter connected to common voltage transformers (VTs) and current transformers (CTs). The meters record load profile data and are read remotely by BC Hydro via a telephone line.

Responsibilities are dependent upon whether the application is:

(a) **Load Only** - where BC Hydro (BCH) is the seller of electricity to the **Customer** (Cust); or

(b) **Generation -** where, the **Power Generator** (PG) is normally the seller of electricity to BC Hydro.

See Section E.9 for specific responsibilities.

E.2 Measurement Canada

The seller of electricity is required by Measurement Canada (MC) to hold a Certificate of Registration and to be in conformance with the *Electricity and Gas Inspection Act and Regulations*.

E.3 Point of Metering

The point of metering may be on either the BC Hydro side or the Customer/Power Generator side of the power transformer.

E.3.1 Metering on BC Hydro Side of the Power Transformer

Metering shall be on the Customer/Power Generator side of the entrance circuit breaker or line isolating disconnect. The following VT and CT connections shall be made:

Metering Elements	VTs	CTs
3	Qty=3, Single Bushing, Group 3b, Connected: • Phase A to Ground • Phase B to Ground • Phase C to Ground	Qty=3, Connected: • Phase A • Phase B • Phase C

E.3.2 Metering on Customer/Power Generator Side of the Power Transformer

A disconnect device shall not be installed between the power transformer and the point of metering to ensure that no-load losses are correctly registered whenever the power transformer is energized. The following VT and CT connections shall be made:

Customer/Power Generator Side of Power Transformer Connection	Metering Elements	VTs	CTs
Delta Or Ungrounded Wye	2	Qty=2, Two Bushing, Connected: • Phase A to B • Phase C to B	Qty=2, Connected: • Phase A • Phase C
Solidly Grounded Wye	3	Qty=3, Single Bushing, Group 3a, Connected: • Phase A to Neutral • Phase B to Neutral • Phase C to Neutral	Qty=3, Connected: • Phase A • Phase B • Phase C
Impedance Grounded Wye	3	Qty=3, Two Bushing, Connected: • Phase A to Neutral • Phase B to Neutral • Phase C to Neutral	Qty=3, Connected: • Phase A • Phase B • Phase C
	2 * (subject to approval)	Qty=2, Two Bushing, Connected: • Phase A to B • Phase C to B	Qty=2, Connected: • Phase A • Phase C

** 2 element metering may be considered as an alternative for impedance grounded wye systems subject to review of ground fault levels and clearing parameters.*

E.3.3 Loss Compensation

If the point of metering is on the Customer/Power Generator side of the power transformer, the main meter will be compensated for transformer losses. Where line losses between the point of metering and the point of interconnection, on either side of the power transformer, are significant, the main meter will be compensated for line losses. The following data, certified by a Professional Engineer, shall be provided by the Customer/Power Generator.

a) Power transformer losses:

- Rated kVA;
- Rated primary voltage;
- Rated secondary voltage;
- No-load (Iron) losses corrected to 75° C;
- Load (Copper) losses corrected to 75° C;
- % Exciting current; and
- % Impedance.

b) Line losses on the BC Hydro side of the power transformer:

- Per phase resistance corrected to 50° C; and
- Per phase inductive reactance.

c) Line losses on the Customer/Power Generator side of the power transformer:

- Per phase resistance corrected to 50° C; and
- Per phase inductive reactance.

E.3.4 Multiple Point of Interconnections

Where there are multiple points of interconnection and/or points of metering, totalization will be performed by adding time synchronized load profile data.

E.3.5 Polarity

The following polarities shall be observed:

a) CT primary polarity marks (H1) shall be towards BC Hydro;

b) 3 element VT polarity marks (H1) shall be towards the phases; and

c) 2 element VT polarity marks (H1) shall be towards A and C phase.

E.3.6 Conventions

Conventions shall be in accordance with the following table:

Convention	Direction	Quadrants	Loss Compensation (where applicable)
kWh delivered	Real power flow from BC Hydro to the Customer/Power Generator	1 & 4	Losses added
kWh received	Real power flow from the Power Generator to BC Hydro	2 & 3	Losses subtracted
kvarh delivered	Reactive power flow from BC Hydro to the Customer/Power Generator (associated with a Customer lagging inductive load)	1 & 2	Losses added
kvarh received	Reactive power flow from the Customer/Power Generator to BC Hydro	3 & 4	Losses subtracted

E.3.7 VT and CT Sequence

The primary VT connections shall be on the BC Hydro side of the CTs.

E.4 Metering VT and CT Configuration

Outdoor Substation Bus Connected VTs and CTs shall be installed in accordance with the following drawings as applicable:

TM-A-1129, Connection At 69 kV Or Above, Primary Metering, Typical CT and VT Arrangement;

a) TM-A-1130, Connection At 69 kV Or Above, Primary Metering, CT and VT Connections;

b) TM-A-1122, Connection At 69 kV Or Above, Secondary Metering At 25 kV Or Below, Outdoor 2 Element CT and VT Connections;

c) TM-A-1124, Connection At 69 kV Or Above, Secondary Metering At 25 kV Or Below, Typical Outdoor 2 Element CT and VT Arrangement;

d) TM-A-1123, Connection At 69 kV Or Above, Secondary Metering At 25 kV Or Below, Outdoor 3 element CT and VT Connections;

e) TM-A-1125, Connection At 69 kV Or Above, Secondary Metering At 25 kV Or Below, Typical Outdoor 3 Element CT and VT Arrangement.

As an alternative, at 69 kV only, combined VT and CT units may be provided.

E.4.1 Switchgear Mounted VTs and CTs

Instrument Transformer Compartment:

The VTs and CTs shall be installed in a switchgear instrument transformer compartment. The instrument transformer compartment shall:

a) Be barriered off from other compartments;

b) Not contain devices other than the revenue metering VTs and CTs;

c) Be not less than 750 mm in width;

d) Be not less than 1500 mm in height;

e) Not require access through other compartments;

f) Have a hinged access door that has a width of not less than 650 mm and a height of not less than 1400 mm;

g) Have provision for locking the hinged access door with a 5/16" shank padlock;

h) Have no means of access other than the hinged access door; and

i) Be permanently labeled as the revenue metering instrument transformer compartment.

In accordance with Section 2 of the *Canadian Electrical Code*, a minimum of 1 m working space shall be provided in front of the instrument transformer compartment.

Interlocks:

For **load only** applications, the instrument transformer compartment door shall be key interlocked with a line side disconnect device. The key interlock shall prevent opening the instrument transformer compartment door unless the disconnect device is visibly open.

For **generation** applications, the instrument transformer compartment door shall be key interlocked with a disconnect on both sides. The key interlocks shall prevent opening the instrument transformer compartment door unless both disconnects are visibly open.

Where the switchgear is on the Customer/Power Generator side of the power transformer, the BC Hydro side disconnect device shall be on the BC Hydro side of the power transformer.

Neutral Bus:

For 3 element metering the neutral bus, or a neutral bus tap extension, shall be routed to the instrument transformer compartment. The neutral bus tap shall be rigid bus and not less than 1" x 1/4".

VTs and CTs:

VTs shall be located in the lower part of the instrument transformer compartment with their primary fuses horizontal. CTs shall be located approximately 600 mm to 1500 mm above the bottom of the instrument transformer compartment.

The H1 and H2 VT and CT primary connections shall preferably be made at the switchgear manufactures factory. If this is not practicable, they may be made at site in accordance with the switchgear manufactures requirements with regard to

clearances, conductor size, fault current bracing etc.

VT primary connections shall be bolted. Drawout or automatic self-disconnecting VT primary connections are not acceptable.

VT and CT primary and secondary terminals shall remain accessible and the nameplates shall remain visible.

Grounding:

The switchgear ground bus, or an extension, shall be accessible in the instrument transformer compartment.

In compliance with the Worker Compensation Board of British Columbia Occupational Health and Safety Regulations, working ground points shall be provided at the following locations in the instrument transformer compartment:

a) On each side of each phase bus current transformer (four points total for 2 element metering, six points total for 3 element metering);

b) In the case of 2 element metering, at a single point on B phase bus;

c) Where the system has a neutral bus, at a single point on the neutral bus; and

d) At a single point on the ground bus.

Working ground points shall:

a) Preferably be a permanently mounted ball type ground stud with a sphere of approximately 25 mm diameter Hubbell Chance C600-2102 or equivalent; or

b) Alternatively be 4 inches of exposed uninsulated bus.

Each working ground point shall be positioned for unobstructed application of a ground clamp using a hot stick.

E.4.2 Lightning Protection

Where exposed to lightning, VTs and CTs shall be protected by lightning arresters.

E.5 VT and CT Primary Connections

The VT and CT primary connections shall:

a) Be supported by means other than the VT and CT bushings;

b) Not subject the VT and CT bushings to strain; and

c) Facilitate the easy replacement of the VT and CT.

E.6 VT and CT Secondary Wiring

In accordance with MC requirements, no other equipment shall be connected to the revenue metering circuits.

69 kV class and greater VTs and CTs supplied by BC Hydro typically have a second set of secondary windings. **Customer** or **Power Generator** access to the second set of secondary windings may be provided for a one-time fee. Where the **Customer** or **Power Generator** elects to use the second set of VT and CT secondary windings:

a) These circuits shall be physically and electrically separated from the revenue metering circuits, i.e. separate cables, conduits, and junction boxes;

b) Use of these windings shall be restricted to the connection of:

- Backup metering;
- Demand or energy management devices;
- Voltmeter, ammeter or other similar instruments; or
- Under-frequency relay.

Note: These windings do not have a protective accuracy rating. Therefore, other than for under-frequency applications, they may not be used for protective relaying.

c) The connected load shall not exceed the maximum nameplate burden; and

d) The VT and CT secondary circuits shall be grounded at single locations only. Failure to comply with this requirement may result in equipment damage and/or personnel injury.

e) The CT secondary circuit shall not be open circuited. Failure to comply with this requirement may result in equipment damage and/or personnel injury.

E.6.1 Junction Box

Where the meter cabinet is remote from the outdoor substation bus VTs and CTs, a revenue metering junction box is required on the VT and CT support structure.

Where the Customer or Power Generator elects to use the second set of VT and CT secondary windings, two junction boxes are required.

Where the meter cabinet is close to the outdoor substation bus mounted VTs and CTs, or the VTs and CTs are installed in switchgear, a junction box is not required.

The BC Hydro supplied junction box is documented in drawing TM-C-1075, Large Weatherproof Junction Box.

E.6.2 Cables

The following applications are typical:

From	To	Cable Types	Conduit or Support
Outdoor substation bus mounted VTs and CTs	Junction Box or Meter Cabinet	Armored cable	Strapped to VT or CT support structure
			Cable tray
Junction Box	Meter Cabinet	Armored cable	Underground conduit
			Cable tray.
Switchgear mounted VTs and CTs	Meter Cabinet	Armored cable	Underground conduit
			Cable tray.
		Individual conductors (pre-twisted and Mylar wrapped)	Indoor or outdoor exposed conduit
			Indoor concrete encased conduit

E.6.3 Conduit

Where armored cable is installed underground, it shall be installed in not less than 3" rigid PVC conduit;

Individual conductors shall be installed in:

a) Indoor or outdoor exposed conduit; or

b) Indoor concrete encased conduit.

Individual conductors shall not be installed in underground conduit.

The conduit shall not be less than1 ¼" rigid metal or EMT, or 1 ½" rigid PVC. The conduit shall have not more than the equivalent of three 90 bends and shall not exceed 25 m in length.

The conduit shall be continuous with no access fittings, except that, "LB style" fittings may be installed if they have provision for the installation of a cover seal.

For switchgear applications, where it is necessary to route VT and CT secondary wiring through other compartments to reach the instrument transformer compartment, the wiring shall be installed in a continuous conduit with no access fittings.

E.7 Meter Cabinet

The main meter, backup meter and associated test blocks shall be installed in a meter cabinet used for no other purpose. The preferred location is inside a dry heated building. If that is not practical, a heated and insulated outdoor meter cabinet may be supplied.

The BC Hydro supplied meter cabinet shall be installed in accordance with drawing G-D08-A160, Indoor And Outdoor Cabinet For Bulk Power Metering Installations. The top of the meter cabinet shall be between 1500 mm and 1550 mm above grade. In accordance with Section 2 of the *Canadian Electrical Code*, a minimum of 1 m working space shall be provided in front of the meter cabinet.

In accordance with Section 36 of the *Canadian Electrical Code*, an external meter cabinet ground conductor, not less than #2/0 AWG copper, shall be provided to bond the meter cabinet to the station ground grid.

A high reliability dedicated 120 V AC 15 A circuit shall be provided at the meter cabinet.

Note: Where there is a critical power bus, supplied via a transfer switch from an emergency generator or multiple supply lines, the meter cabinet shall be supplied from the critical power bus. However, battery powered UPS supply is not required.

E.8 Telephone Line

A telephone line and line switcher shall be provided for remote reading of the main meter and backup meter. Conventional wire-line or alternative technologies may be used, e.g. cellular, fiber optic, microwave, satellite etc.

Where wire-line circuits are used, ground potential rise (GPR) protection shall be designed, installed and maintained in accordance with *IEEE Standard 487 Guide for the Protection of Wire-Line Communication Facilities Serving Electric Power Stations*. Failure to follow this standard may result in equipment damage and/or personnel injury.

E.9 Responsibilities

Specific responsibilities shall be in accordance with the following table:

- BCH BC Hydro
- Cust Customer (for Load Only applications)
- PG Power Generator (for Generation applications). All costs will be the responsibility of the PG.

Section Reference	Item		Load Only	Generation
			By	By
E.2.	MC Certificate of Registration	Documentation	BCH	PG
E.4.	VT	Material	BCH	BCH
		Support Structure or Instrument Transformer Compartment	Cust	PG
		Installation	Cust	PG

Section Reference	Item		Load Only	Generation
			By	By
		Primary Connections	Cust	PG
		Secondary Connections	BCH	BCH
E.4.	CT	Material	BCH	BCH
		Support Structure or Instrument Transformer Compartment	Cust	PG
		Installation	Cust	PG
		Primary Connections	Cust	PG
		Secondary Connections	BCH	BCH
E.6.1	Junction Box	Material	BCH	BCH
		Installation	Cust	PG
E.6.2	Cable between VTs/CTs, Field Junction Box and/or Meter Cabinet	Material	BCH	BCH
		Installation	Cust	PG
		Connections	BCH	BCH
		Conduit and/or support	Cust	PG

Section Reference	Item		Load Only	Generation
			By	By
E.7	Main Meter	Material	BCH	BCH
		Initial Verification and Sealing	BCH	BCH
		Subsequent Periodic Reverification and Resealing	BCH	BCH
		Installation	BCH	BCH
	Main Meter Test Block	Material & Installation	BCH	BCH
E.7	Backup Meter	Mounting Space Adjacent to Main Meter	BCH	BCH
		Material	BCH	BCH
		Initial Verification and Sealing	BCH	BCH
		Subsequent Periodic Reverification and Resealing	BCH	BCH
		Installation	BCH	BCH

Section Reference	Item		Load Only	Generation
			By	By
E.7	Meter Cabinet	Material	BCH	BCH
		Installation	Cust	PG
E.7	Meter Cabinet Ground	Material & Installation	Cust	PG
E.7	Meter Cabinet Auxiliary Power	Material & Installation	Cust	PG
E.8	Telephone Line	Installation Coordination	BCH & Cust	BCH & PG
		Installation Cost	BCH	PG
		Operating Cost	BCH	PG
E.8	Telephone Line GPR Protection	Material & Installation	BCH	BCH

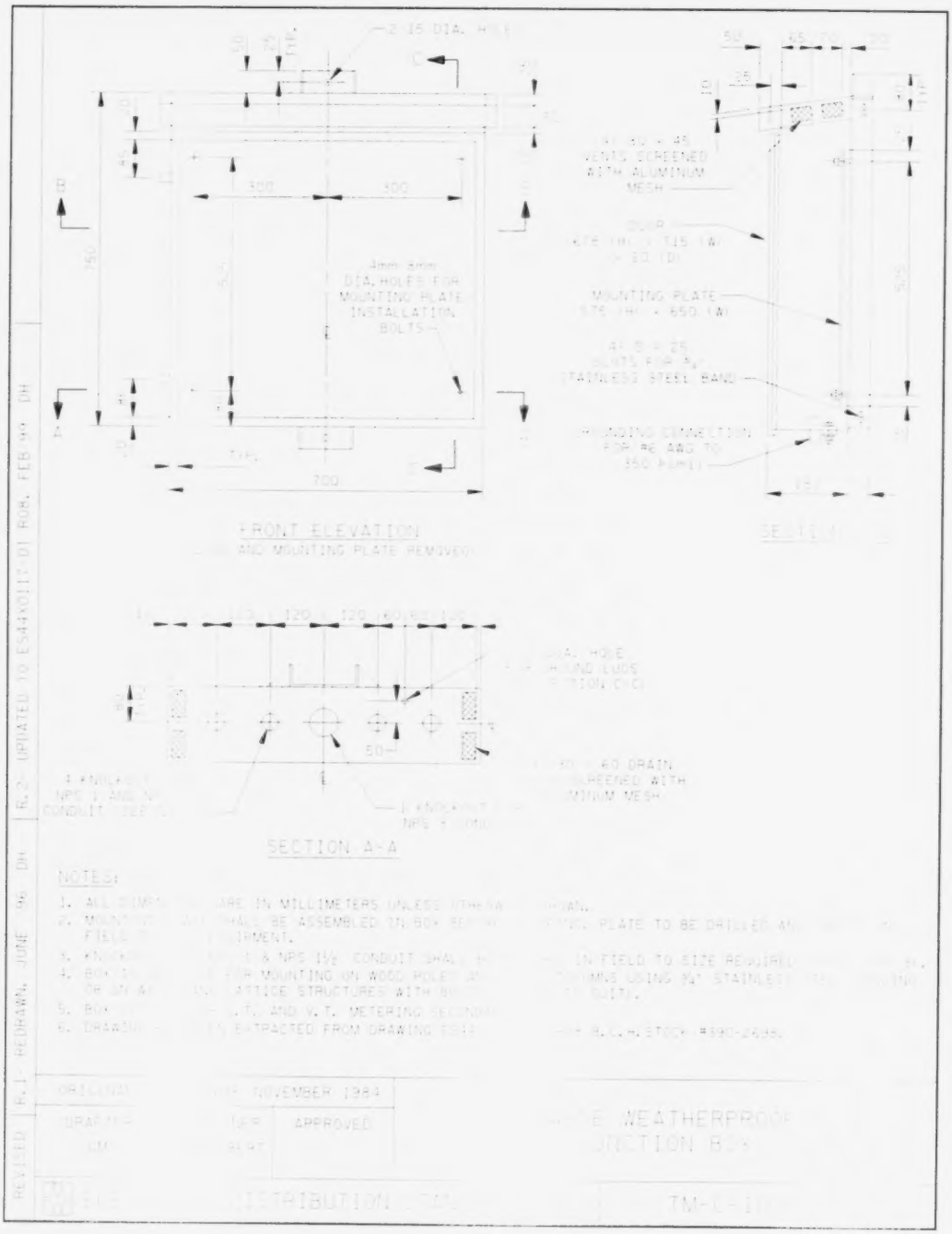
E.10 Commissioning

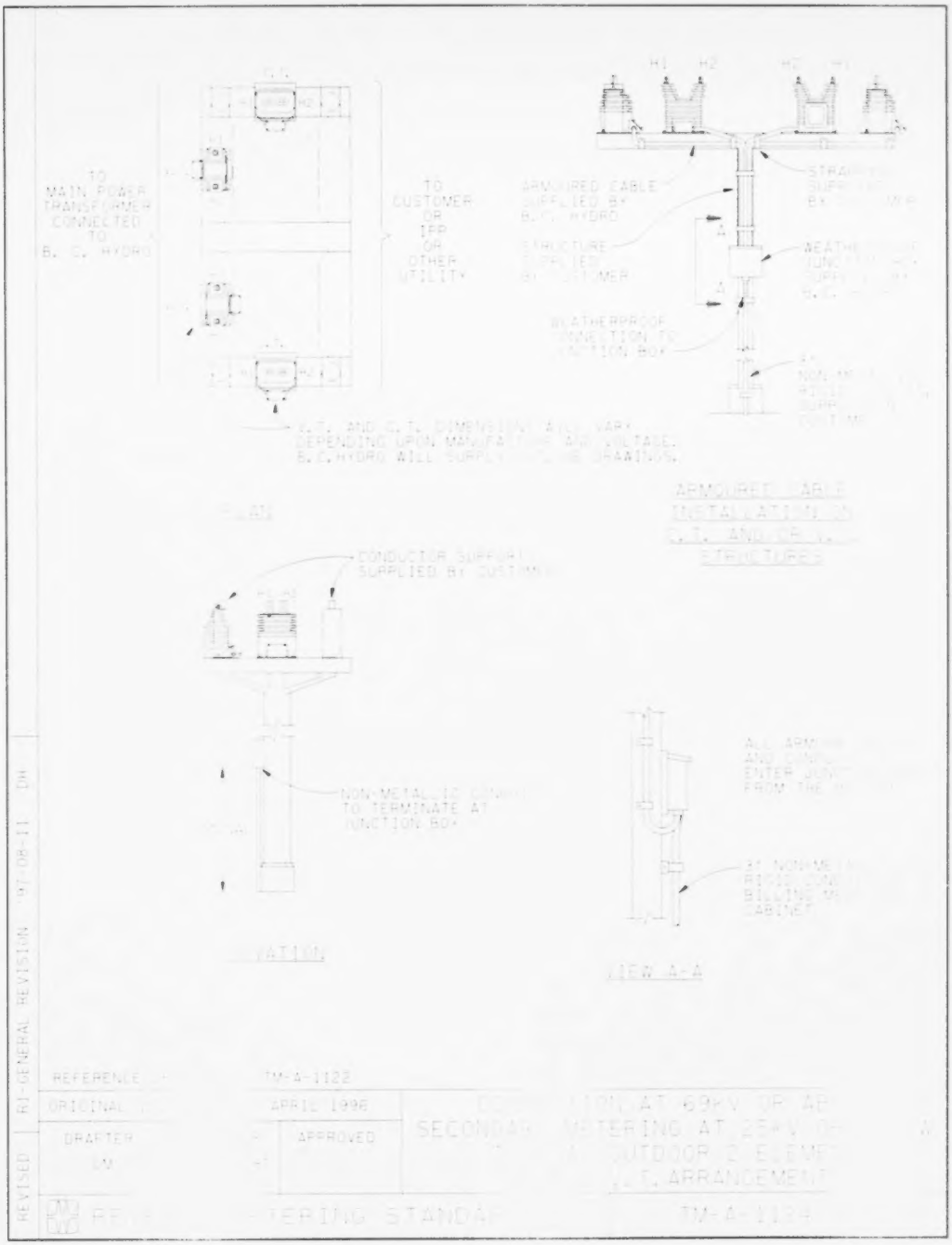
All BCH supplied materials will be commissioned by BCH at the cost of the PG.

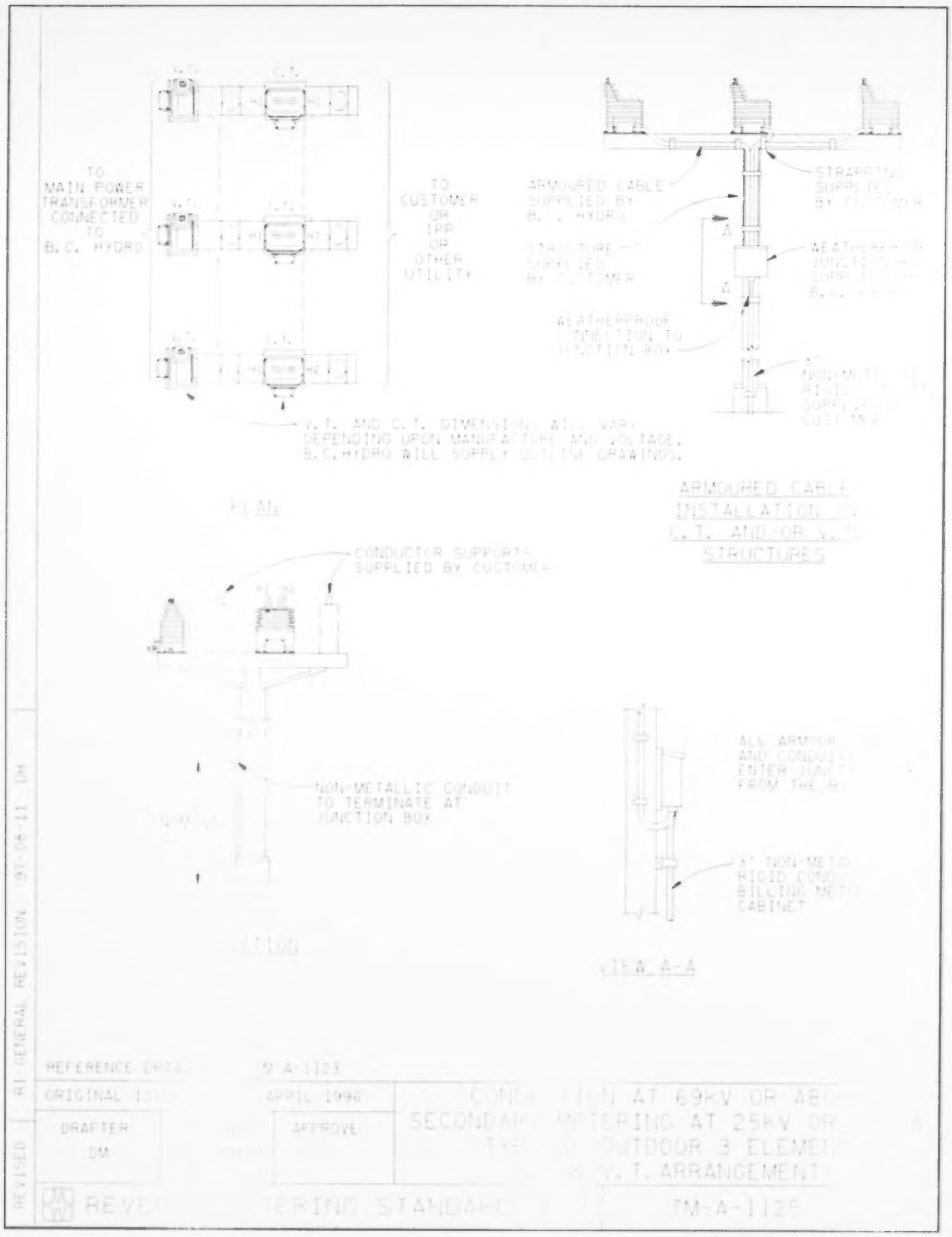
E.11 Maintenance

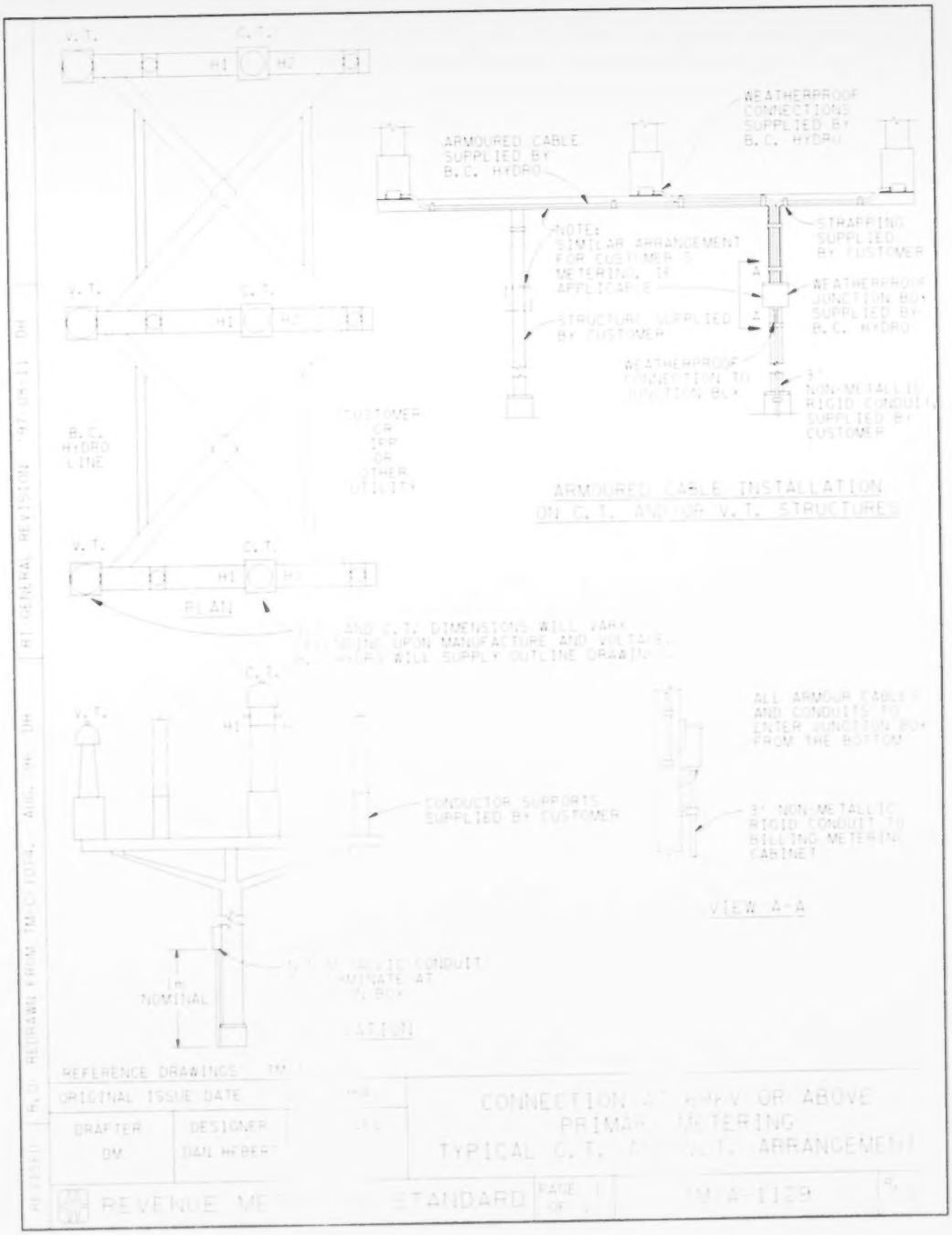
All maintenance on BCH supplied materials will be performed by BCH at the PG's expenses. Warranty issues on manufacturer's equipment will be handled through BCH.

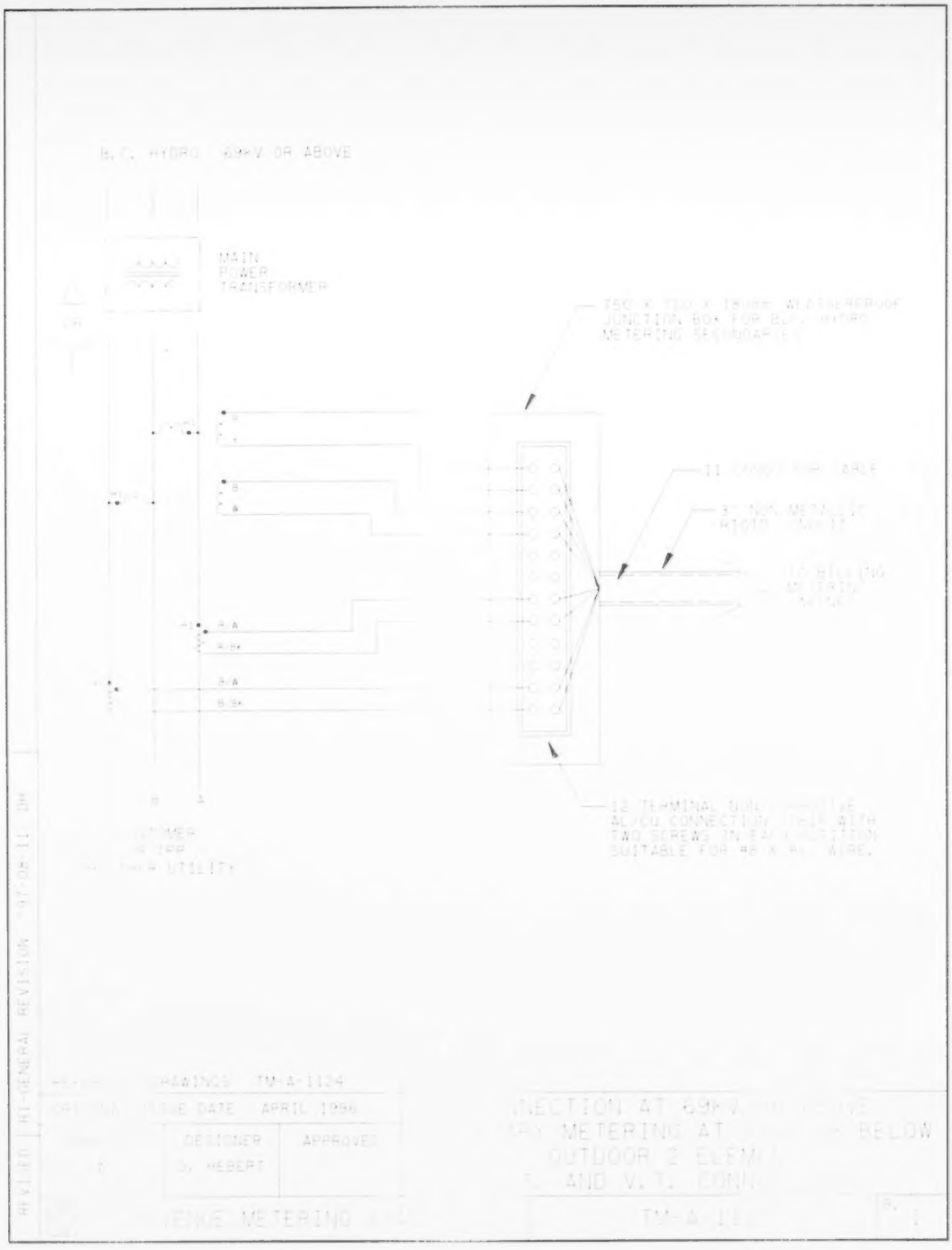
E.12 Revenue Metering Standard Drawings

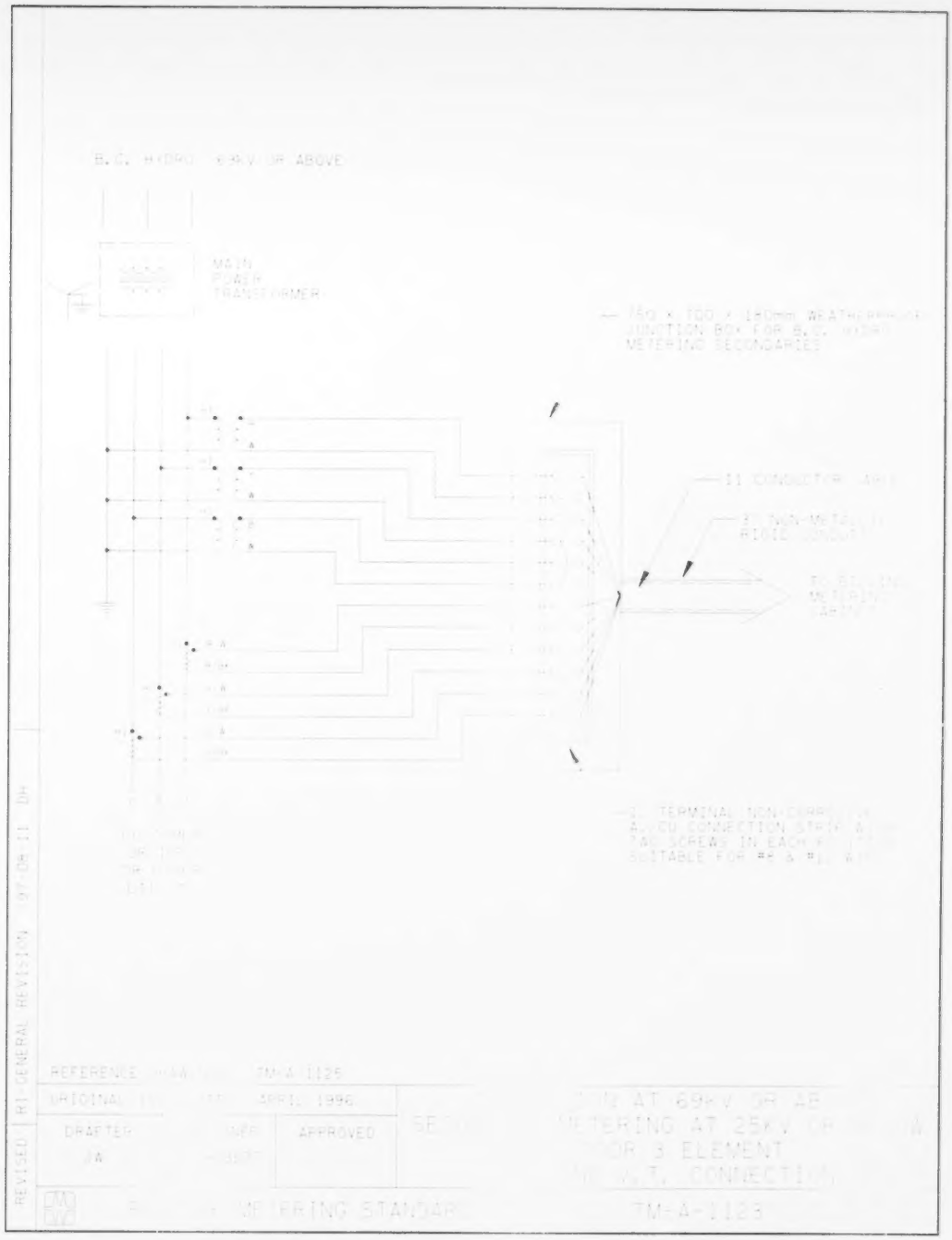



TO MAIN POWER TRANSFORMER CONNECTED TO B. C. HYDRO
TO CUSTOMER OR IPP OR OTHER UTILITY
ARMOURED CABLE SUPPLIED BY B.C. HYDRO
STRUCTURE SUPPLIED BY CUSTOMER
WEATHERPROOF CONNECTION TO JUNCTION BOX
C.T. AND C.T. DIMENSIONS WILL VARY DEPENDING UPON MANUFACTURER AND VOLTAGE. B.C. HYDRO WILL SUPPLY THE DRAWINGS.
ARMOURED CABLE INSTALLATION ON C.T. AND P.T. STRUCTURES
PLAN
CONDUCTOR SUPPORT SUPPLIED BY CUSTOMER
NON-METALLIC CONDUIT TO TERMINATE AT JUNCTION BOX
ELEVATION
VIEW A-A
REVISED BY GENERAL REVISION '97-08-11 DH
REFERENCE TM-A-1122
ORIGINAL APRIL 1996
DRAFTER LM
APPROVED
SECONDARY METERING AT 69kV OR AB
OUTDOOR 2 ELEMENT
C.T. ARRANGEMENT
TM-A-1134


TO MAIN POWER TRANSFORMER CONNECTED TO B.C. HYDRO
TO CUSTOMER OR IPP OR OTHER UTILITY
V.T. AND C.T. DIMENSIONS AT... VARY DEPENDING UPON MANUFACTURE AND VOLTAGE. B.C.HYDRO WILL SUPPLY OUTLINE DRAWINGS.
PLAN
ARMOURED CABLE SUPPLIED BY B.C. HYDRO
STRUCTURE SUPPLIED BY CUSTOMER
WEATHERPROOF CONNECTION TO JUNCTION BOX
ARMOURED CABLE INSTALLATION ... C.T. AND/OR V.T. STRUCTURES
CONDUCTOR SUPPORTS SUPPLIED BY CUSTOMER
NON-METALLIC CONDUIT TO TERMINATE AT JUNCTION BOX
VIEW A-A
REFERENCE DRAWING TM A-1133
ORIGINAL ISSUE APRIL 1996
DRAFTER DM
APPROVE
REVISED AT GENERAL REVISION 97-08-11 DM
TM-A-112


V.T.
C.T.
H1
H2
WEATHERPROOF CONNECTIONS SUPPLIED BY B.C. HYDRO
ARMOURED CABLE SUPPLIED BY B.C. HYDRO
NOTE: SIMILAR ARRANGEMENT FOR CUSTOMER'S METERING, IF APPLICABLE
STRAPPING SUPPLIED BY CUSTOMER
WEATHERPROOF JUNCTION BOX SUPPLIED BY B.C. HYDRO
STRUCTURE SUPPLIED BY CUSTOMER
WEATHERPROOF CONNECTION TO JUNCTION BOX
3" NON-METALLIC RIGID CONDUIT SUPPLIED BY CUSTOMER
B.C. HYDRO LINE
CUSTOMER OR IPP OR OTHER UTILITY
ARMOURED CABLE INSTALLATION ON C.T. AND/OR V.T. STRUCTURES
PLAN
ALL ARMOUR CABLES AND CONDUITS TO ENTER JUNCTION BOX FROM THE BOTTOM
CONDUCTOR SUPPORTS SUPPLIED BY CUSTOMER
3" NON-METALLIC RIGID CONDUIT TO BILLING METERING CABINET
VIEW A-A
NOMINAL
REFERENCE DRAWINGS
ORIGINAL ISSUE DATE
DRAFTER
DM
DESIGNER
DAN HEBER
REVENUE ME
STANDARD


B.C. HYDRO 69KV OR ABOVE
MAIN
POWER
TRANSFORMER
REVISED AS GENERAL REVISION
DESIGNED
APPROVED
M. HEBERT
REVENUE METERING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MAIN
POWER
TRANSFORMER
REVISED - GENERAL REVISION - 97 09 11 DH
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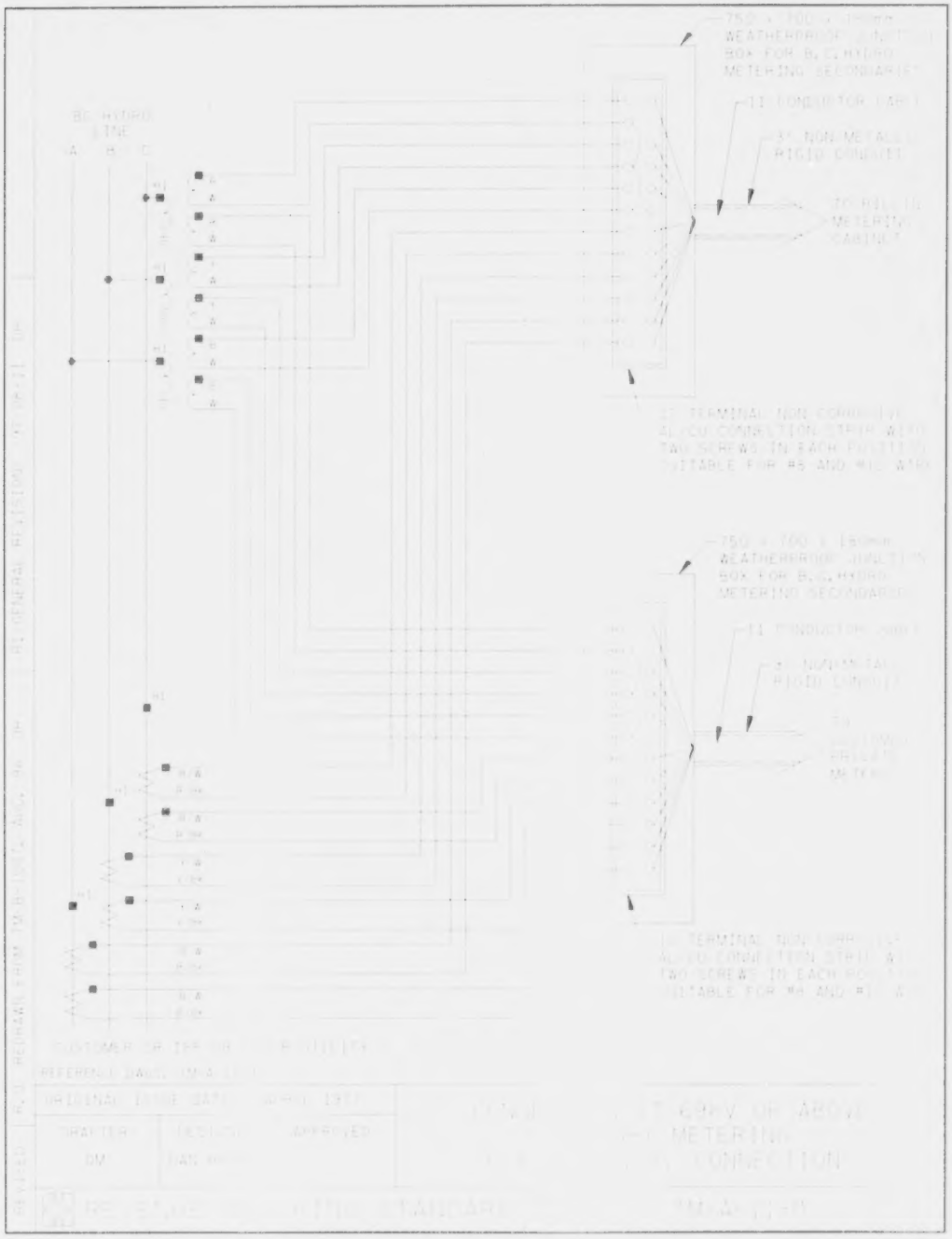
TM-A-1125



F DATA REQUIREMENTS

The following outlines data that will be required at various stages of planning, design, commissioning and in-service of the PG's commercial project. This data is required by BCH to ensure suitable steps are taken to interconnect the PG to the BCH system.

F.1 Submission Requirements

Wherever possible, all documents shall be provided in both paper and electronic form.

The preferred format for reports and other documents is Word for Microsoft Office97 and for data, drawing indexes and the like is Excel for Microsoft Office97.

The preferred formats for drawings are (in order of preference): (i) Auto-CADD *.DXF format, (ii) Intergraph MicroStation *.DGN format, or (iii) Portable Document Format (PDF).

Unless legibility will be a problem, all drawings must be submitted on either, 'A'-size (8.5" x 11"; 21.6cm x 27.9cm), or 'B'-size, sheets (11" x 17"; 27.9 cm x 43.2 cm).

F.2 General Submissions

a) Six (6) copies of the previously submitted Preliminary Study Application Form.

b) Six (6) copies of completed Transmission Entrance Equipment Statement sealed by a Professional Engineer.

c) Six (6) copies of completed Generator Equipment Statement sealed by a Professional Engineer.

d) Six (6) copies of the generating station electrical one-line diagram, three-line AC schematic and DC schematic.

e) Six (6) copies of the protective relay setting sheets.

f) Six (6) copies of the generating station site plan.

g) Six (6) copies of the generating station layout and elevation drawings.

h) Six (6) copies of drawings showing provisions for BC Hydro metering transformer, metering cubicle and required cabling and wiring.

i) Six (6) copies of generating station grounding drawings showing all ground connections.

j) Six (6) copies of the station service requirements (load characteristics, start-up power, voltage dips when the plant is not running, etc).

k) Six (6) copies of the generator open circuit saturation curve.

l) Six (6) copies of the generator capability curve.

m) Six (6) copies of the PG's maintenance plan.

n) Six (6) copies of the PG's commissioning test plan.

F.3 EMTP Data

For thermal turbine-generator units rated larger than 100 MVA, the following mechanical data must be provided so that a multi-mass (spring-mass-dashpot) mechanical model can be constructed:

a) Number of lumped rotating masses on the turbine generator shaft,

b) Moment of inertia (lb.-mass ft^2) of each lumped mass,

c) The fraction of the total external mechanical torque of which is applied to the particular mass under consideration,

d) The spring constant [(million pound-ft)/radians] of the shaft section between the present mass and the next one on the shaft,

e) The speed deviation self damping coefficient for the mass under consideration,

The mutual damping coefficient pertaining to the present mass with the next mass on the shaft.

F.4 Generating Unit Testing and Model Validation

All generators interconnecting to BCH shall be tested by qualified personnel in accordance with the WSCC's 1997-Mar-21 letter, requesting generator testing and model validation of generators in the WSCC, and its attachments.

The WSCC's 19997-Mar-21 letter and the associated documents are available from the WSCC's web-site.

The main objectives of the WSCC's request were:

a) To confirm each generator's over-and under-excited Mvar capabilities.

b) To confirm that each generator is being operated in automatic voltage control mode.

c) To confirm proper governor settings, particularly droop and dead band.

d) To confirm that all controls, limiters and protective relays are properly coordinated to provide adequate protection of the individual generating units and their components while maximizing their contribution to the control of system over- and under-voltages and over- and under-frequencies during major system disturbances.

e) To validate the models used to represent each generating unit in system operating and planning studies.

This section provides a general specification of deliverables for generator testing. Its objective is to ensure that the information and test data provided in generating unit test reports is sufficient for the development and validation of simulation study models in accordance with the WSCC's 1997-Mar-21 request for testing and model validation of all generating units rated 10 MVA and larger.

F.4.1 Summary of Tests Needed for Model Validation

The following is a summary of the tests needed to develop and properly validate the models used in system simulation studies (powerflow and dynamic simulation studies). The tests preceded by an asterisk (*) are specifically included in the WSCC's February 1997 dynamic test guidelines or in the WSCC's steady-state test guidelines. Unless otherwise noted, the referenced figures are from the WSCC's dynamic test guidelines.

a) *** Open-circuit Saturation Test**

This test is to determine the generator saturation factors S_{10} and S_{12} (refer to Figure D of the WSCC guidelines)

The unit should be brought to the synchronous speed and disconnected from grid (off-line) with no field current. The field current will then be increased in steps of 10% until the generator armature voltage reaches 120% of the rated value.

The generator armature voltage (V_t), field voltage (V_f) and field current (I_f) will be recorded, in tabular form, at each step.

Step #	Armature voltage (kV)	Field voltage (V)	Field current (A)
1			
2			
...	...	...	...
x			

b) *** Moderate Load Trip Test**

This test is to validate (1) unit inertia constant, H (MW.s/MVA), (2) governor droop and model parameters (refer to Figures A and G of the WSCC guidelines).

The machine should be loaded to a small amount of MW (around 10 - 20% to prevent the interference from protection relay operation) and Mvar value (under-excited condition preferred). The AVR should be set in auto control mode and the governor set in speed droop control mode. The unit circuit breaker input signal to the turbine controller should be blocked to defeat the machine speed preset. The unit circuit breaker will then be opened to disconnect the unit from grid.

The time response of the following machine quantities needs to be recorded:

- Machine speed (Hz)
- Generator active power output (MW)
- Generator reactive power output (Mvar)
- Generator armature voltage (kV)
- Load/speed reference value (V)
- Valve position (V)
- Governor output (V)

Note that the recording should start before opening the unit circuit breaker, and stop after the machine speed settles down (about 60 seconds after tripping the unit).

c) *** D-Axis Trip Test**

This test is to calculate D-axis unsaturated impedances and time constants (refer to Figure C of the WSCC guidelines).

The unit should be synchronized to the system and adjusted to supply 0 MW, or as close to 0 MW as possible, and approximately –10 Mvar (under excited) with the AVR on manual control. The reverse power relay may need to be blocked. The unit breaker is then opened to disconnect the unit from grid.

The time response of the following machine quantities needs to be recorded:

- Machine speed (Hz)
- Generator active power output (MW)
- Generator reactive power output (Mvar)
- Generator armature voltage (kV)
- Generator field voltage (V)
- Generator field current (A)

Note that the recording should start before opening the circuit breaker and stop after the generator voltage reaches a steady value (about 30 seconds after tripping the unit).

Important - a high sampling rate for generator terminal voltage is required in this specific test.

d) * **Line-Drop Compensator (LDC) Test**

This test is to determine the LDC setting or verify that it is set to zero (refer to Figure F of the WSCC guidelines).

This test is to determine the line drop compensation setting. The unit should be synchronized to the system and adjusted to supply 0 MW and approximately -10 Mvar. The AVR is in automatic mode. The unit circuit breaker is then opened, disconnecting the unit from the system.

The time response of the following machine quantities needs to be recorded:

- Generator active power output (MW)
- Generator reactive power output (Mvar)

- Generator armature voltage (kV)
- Generator field voltage (V)
- Generator field current (A)

e) *** Reactive Power Capability Test**

This test is to determine the machine's capability to generate/absorb the reactive power.

The unit should be first loaded at rated MW load. Then the field current is slowly increased to determine the machine's capability to supply the reactive power. Similarly, the field current is slowly decreased to determine the machine's capability to absorb the reactive power. The unit must stay on line for this test (no protection trip), and held for 15 minutes at each knee point to ensure the limit can be held. BC Hydro's Control Centre must be involved with this test.

At the maximum var output point, record the following data, in a tabular form:

- Generator reactive power output (Mvar)
- Generator active power output (MW)
- Generator armature voltage (kV)
- Generator field voltage (V)
- Generator field current (A)
- Station service voltage if applicable (V)
- Reasons for limiting the generator to supply more reactive power.

Similarly at the maximum var absorption point, record the following data:

- Generator active power output (MW)
- Generator reactive power absorption (Mvar)
- Generator armature voltage (kV)
- Generator field voltage (V)
- Generator field current (A)

- Station service voltage if applicable (V)
- Reasons for limiting the generator to absorb more reactive power.

f) **Exciter Step Response Test**

This test is to determine the response of the exciter and validate the parameters of excitation system model.

Run the machine at full speed and 95% rated voltage with the unit circuit breaker open. The AVR is set in automatic control mode. Apply a small step change (3-5%) in the exciter voltage reference point. Repeat the test again with a large step (10%).

The following quantities are to be recorded for each step test:

- Generator armature voltage (kV)
- Generator field voltage (V)
- Generator field current (A)
- Exciter reference voltage (V)
- Automatic voltage regulator output (V)

g) **Over Excitation Limiter (OEL) Test**

This test is to verify OEL setting and its dynamic performance, and coordination with protective relays (refer to Figure D of the WSCC guidelines).

With the unit spinning at synchronous speed, off-line no load, the generator terminal voltage is adjusted to 95% rated value. The AVR is set in automatic control mode. A 10% step change is introduced into the reference setting of the exciter to produce a 10% increase in terminal voltage. Observe to confirm the operation of over excitation limiter.

The following data need to be recorded:

- Generator field voltage (V)
- Generator field current (A)
- Generator armature voltage (kV)
- Exciter reference voltage (V)

- OEL limiter output (V)

h) **Under Excitation Limiter (UEL) Test**

This test is to verify UEL setting and its dynamic performance, and coordination with protective relays (refer to Figure D of the WSCC guidelines).

With the unit spinning at synchronous speed, off-line no load, the generator terminal voltage is adjusted to 95% rated value. The AVR is set in automatic control mode. A 10% step change is introduced into the reference setting of the exciter to produce a 10% decrease in terminal voltage. Observe to confirm the operation of under excitation limiter.

The following data need to be recorded:

- Generator field voltage (V)
- Generator field current (A)
- Generator armature voltage (kV)
- Exciter reference voltage (V)
- UEL limiter output (V)

i) *** Volts/Hz Limiter Test**

This test is to verify the performance of the VHL at off-synchronous speed and confirm that it is coordinated with protective relays (refer to Figure J of the WSCC guidelines).

Run the machine at full speed no load and rated voltage. The unit is disconnected from the grid. The AVR is set in automatic control mode. Introduce a step change in the exciter voltage reference point so that there will be at least 5% step increase in the terminal voltage. Monitor the V/Hz limiter output to check its response. If the limiter doesn't operate with the small step change, introduce a larger step to perform the test.

Record the following quantities:

- Generator armature voltage (kV)
- Generator field voltage (V)
- Generator field current (A)

- Exciter reference voltage (V)
- V/Hz limiter output (V)
- AVR output (V)

j) **PSS Step Response Test**

This test is to determine the parameters of the Power System Stabilizer model.

With the PSS isolated, apply a step change to the first PSS input channel and record the PSS response at its intermediate and final stages. The same test should be repeated for the second PSS input (if any).

k) *** PSS Performance on-line Test**

This test is to verify the PSS performance to improve the damping of machine local mode oscillations.

With the unit on-line and operating at rated MW load, apply a step change to the exciter voltage reference point. Record the time response of generator terminal voltage and output powers (MW and Mvar) with PSS off. Repeat the test with PSS on.

Note - BC Hydro will supply the final value of the PSS setting.

l) **Governor Step Response Test (off-line)**

This test is used to determine the parameters of turbine and governing system.

Run the machine at synchronous speed, off-line no load, and set the governor in speed-droop control mode (not isochronous mode). Apply a 3% step change to the load/speed reference and record the time response of following quantities:

- Load/speed reference value (V)
- Machine speed (Hz)
- Valve position (V)
- Speed governor output (V)

m) **Governor Step Response Test (on-line)**

This test is also used to determine the parameters of turbine and governing system.

Adjust generator MW output to supply approximately 50% rated MW output, and set the governor in speed-droop control mode (not isochronous mode). Apply a step 5% change to the load/speed reference and record the time response of following quantities:

- Generator active power output (MW)
- Generator reactive power output (Mvar)
- Generator armature voltage (kV)
- Load/speed reference value (V)
- Machine speed (Hz)
- Valve position (V)
- Speed governor output (V)

n) **Wide Range Droop Test**

In case that the moderate load rejection test (b) cannot be performed successfully, the following two-part test will be conducted to determine the droop of speed governing system.

Part I: Machine Speed Vs Speed Reference Value

Bring the machine close to synchronous speed and with the unit breaker open. Using the speed/load reference to change the machine speed and record the governor reference input at different speed. At least three points need to be recorded in the following tabular format.

Machine speed (RPM) (for example)	Speed/load reference setting value (V)
3400	
3500	
3600	
3700	

Part II: Machine MW Output Vs Speed Reference Value

The unit is connected to grid and loaded to its rated MW output. Record the governor reference input, and machine MW output, for 70%, 80%, 90% and 100% of rated MW loading (using the speed/load reference set point). The following data need to be recorded:

Generator MW output (MW)	Speed/load reference setting value (V)

F.5 Generator Equipment Statement

Generator Equipment Statement

BC hydro

Applicant Information

Applicant

Company Name:	Contact Address:
Contact Name:	
Phone:	Street / Unit/Suite
Fax:	
E-Mail:	City / Province
	Postal Code / Country

Project Information

Project

Project Name:	Project Location:(Please provide location description and map)
Project Owner/Developer:	
Project Engineering Consultant:	
Proposed In-Service Date:	

Generator Information

Generator

1. Unit Designation	2. Manufacturer	3. Model	4. No. of Phases	5. Output Frequency (Hz)	6. Maximum Power Output (MVA)

7. Rated Power Output (MVA)	8. Rated Voltage (kV)	9. Synchronous Speed (RPM)	10. Inertia Constant - H (MW-sec/MVA)	11. Moment of Inertia - WR^2 ($lb\text{-}ft^2$)

12. Energy Source H - Hydraulic G - Gas W - Woodwaste O - Other	13. Type S - Synchronous I - Induction O - Other	14. 1 pu Field Current (non-Reciprocal system) (Amps)	15. 1 pu Field Voltage (non-Reciprocal system) (Volts)	16. Base Terminal Voltage (kV)

17. Base MVA	18. Base Field Voltage (Volts)	19. Base Field Current (Amps)	20. Max. Continuous Field Voltage (Volts)	21. Max. Continuous Field Current (Amps)

22. Max. 30s Field Current (Amps)	23. Field Ceiling Voltage (Volts)	24. Resistance Values			
		R_a (Armature)	@ Op. Temp.	R_f (Field)	@ Op. Temp.

25. Open Circuit Time Constants (Unsaturated Values)				26. Short Circuit Time Constants (Unsaturated Values)				
T'_{do}	T''_{do}	T'_{qo}	T''_{qo}	$T_{A\,Gen}$	T'_D	T''_D	T'_Q	T''_Q

27. Reactance in % of Generator MVA Base (Unsaturated Values)						28. Power Factor Range
X_d	X'_d	X''_d	X_q	X'_q	X''_q	From: To:

28. Open Saturation Curve (Attach)

Exciter Information

Exciter

1. Manufacturer	2. Model	3. Type	4. IEEE Model Type	5. Max. Continuous Field Voltage (kV)

6. Max. Continuous Field Current (Amps)	7. Max. 30s Field Current	8. Nameplate Field Ceiling Voltage	9. Control Mode P - Power S - Speed F - Frequency

10. Dynamic Model Block Diagram (Attach)

Power System Stabilizer Information

PSS

1. Manufacturer	2. Type	3. Control Input (1) P - Power S - Speed F - Frequency	4. Control Input (2) P - Power S - Speed F - Frequency	5. Dynamic Model Block Diagram (Attach)

Governor and Turbine Information

Governor / Turbine

1. Governor Manufacturer	2. Governor Type	3. Turbine Manufacturer	4. Turbine Type

5. Inertia Constant - H (Generator and Turbine) (MW-sec/MVA)	6. Moment of Inertia - WR^2 (Generator and Turbine) ($lb\text{-}ft^2$)

7. Governor/Turbine Dynamic Model Block Diagram (Attach)	8. 25%, 75%, and 100% Load Rejection Speed Rise Calculations and Graphs (Attach)

Submission Information

Submission

Seal of Professional Engineer of British Columbia

Print Name

Signature

Date:

The Power Generator (PG) provides this Statement to BC Hydro knowing that BC Hydro intends to rely upon this data for study purposes. Any subsequent changes in the submitted data may result in BC Hydro performing additional studies at the expense of the PG.

BC Hydro - Generator Interconnections Office Use

Received By:

Date and Time Received:

Signature

F.6 Transmission Entranced Equipment Statement

Transmission Entrance Equipment Statement

BC hydro

Applicant Information

Applicant

Company Name:	Contact Address:
Contact Name:	
Phone:	Street / Unit/Suite
Fax:	
E-Mail:	City / Province
	Postal Code / Country

Project Information

Project

Project Name:	Project Location (Please provide location description and map):
Project Owner/Developer:	
Project Engineering Consultant:	
Proposed In-Service Date:	

Drawing Information

Drawings

1. Attach One-Line, Site Plan and Layout Drawings

One-Line Drawing No. _____
Site Plane Drawing No. _____
Layout Drawing No. _____

Transmission Line Information

Transmission

2. Interconnection Voltage (kV)	3. Line Length to Point of Interconnection (km)	4. Conductor Size	5. Conductor Impedances Totals (per phase) R_0 (Ω)	R_1 (Ω)	X_0 (Ω)	X_1 (Ω)	Y_0 (mho)	Y_1 (mho)

6. Line Clearance to Ground (m) Maximum	Minimum	7. Maximum Tower/ Pole Height (m)	8. Minimum Tower/ Pole Height (m)	9. Maximum Line Rating (Amps) Summer	Winter

10. Conductor Phase Spacing (m) A-B	B-A	C-A	11. Attached Typical Tower or Poll Configuration Drawing

Transformer Information

Transformer

12. Unit Designation (i.e., T1)	13. Manufacturer	14. MVA Ratings Stage 1: Stage 2: Stage 3:	15. HV Winding Voltage (kV)	16. HV Connection D - Delta Y- Wye YG - Grounded Wye	17. LV Winding Voltage (kV)	18. LV Connection D - Delta Y- Wye YG - Grounded Wye

19. Impedance (%) Z_{pos}	Z_0	20. Sequence Impedance (Per Unit of Transformer Base) R_0	R_1	X_0	X_1	G_0	G_1	B_0	B_1	21. Loses No-Load (kW)	Full-Load (kW)

22. HV Basic Insulation Level (kV)	23. LV Basic Insulation Level (kV)	24. Tap Changer Location (HV/LV)	Type (Load/Off-Load)	No of Taps Above Below	Tap % Step

Circuit Breaker Information

Breaker

25. Unit Designation (i.e., CB1)	26. Manufacturer	27. Model	28. Voltage Rating (kV)	29. Continuous Current Rating (Amps)	30. Interrupting Rating (kA Sym RMS)	31. Interrupting Time (Cycles)

Protection Information

Protection

Relay	Manufacturer	Model	Timed Element Setting Range	Inst. Element Setting Range
32. Ground Overcurrent				
33. Phase Overcurrent				
34. Over/Under Frequency				
35. Over/Under Voltage				
36. Transformer Differential				
37. Generator Differential				
38. Bus Differential				
39. Synchronizing Check				
40. Reverse Power				
41. Line				

Protection C.T.'s must be adequate for all fault duty magnitudes.

Submission Information

Submission

Seal of Professional Engineer of British Columbia

Print Name

Signature

Date:

The Power Generator (PG) provides this Statement to BC Hydro knowing that BC Hydro intends to rely upon this data for study purposes.

Any subsequent changes in the submitted data may result in BC Hydro performing additional studies at the expense of the PG.

BC Hydro - Generator Interconnections Office Use

Received By:

Date and Time Received:

Signature

F.7 Generator Outage Data

BC Hydro has implemented a system of continuous reporting of generation equipment status and reports the data to the Canadian Electricity Association (CEA) and to the North American Electric Reliability Council (NERC) in the United States.

The reporting procedure as described in Power Supply System Operating Order 1P-14 (Generation Equipment – Status Reporting) is based on a method developed by the CEA of assigning "states" to the operation of a unit.

Prior to full commercial in-service, the PG will be supplied with a copy of this System Operating Order and will be expected to submit collected data within 5 days of the end of each month to BCH.

G DECLARATION OF COMPATIBLITY

The PG shall comply with the various levels of Declarations of Compatibility as listed below. These declarations refer to key aspects where BCH must be confident of the correct operation, setting, calibration and/or installation of equipment.

Each declaration must be signed by BC Hydro and the Power Generator agreeing that the PG's Interconnection is compatible with the BC Hydro system and is capable of receiving electricity, generating electricity for commissioning purposes, or full commercial generating electricity.

This may include, but is not limited to, generator performance, protective relaying, telecommunications, revenue metering, and shall confirm the compatibility of the PG's equipment and controls with BC Hydro's systems where applicable.

G.1 Requirements for "Declaration of Compatibility – Load":

The compatibility of load describes conditions that must be satisfied before the PG's facility can be connected to receive electricity from BC Hydro and usually occurs during construction.

Declaration of Compatibility
Load
Generator's Facilities

Generator:

Project:

The Generator shall design, construct, own, and maintain the Customer's Facilities.

	Yes	No
Interconnection		
1. Executed Interconnection Agreement	☐	☐
2. BC Hydro has reviewed the Generator's proposed facilities to confirm compliance with BC Hydro's technical requirements for operation as a load.	☐	☐
Field Verification		
1. Protective Relay Coordination confirmed.	☐	☐
2. Revenue Metering Installation completed and checked. Attach BC Hydro Metering Checklist.	☐	☐
3. Local Operating Order approved by BC Hydro and the Generator. Generator and Control Centre have copies.	☐	☐
4. Electrical Inspection Approval attached.	☐	☐
5. Professional Engineer's declaration(s) that the Generator's Facilities have been designed, constructed, and tested to a state suitable for operation as a load in accordance with prudent electrical utility practice.	☐	☐
6. BC Hydro facilities ready.	☐	☐

Provide explanation if "No" has been checked for any item above.

The undersigned do hereby declare that the Generator's Substation is compatible for interconnection with the BC Hydro system for the purposes of operating as a load.

_____ _____ _____ _____
(Generator or Delegate) *Date* *(BC Hydro Field Coordinator)* *Date*

G.2 Requirements for "Declaration of Compatibility – Generator (1st Synchronization)"

The compatibility of generation (1st Synchronization) describes conditions that must be satisfied before the PG's facility can be connected to generate electricity for the purposes of testing and commissioning the facility or its components.

Declaration of Compatibility
Generator (1st Synchronization)
Generator's Facilities

Generator:

Project:

The Generator shall design, construct, own, and maintain the Customer's Facilities.

	Yes	No
Interconnection		
1. Executed Interconnection Agreement	☐	☐
2. BC Hydro has reviewed the Generator's proposed facilities to confirm compliance with BC Hydro's technical requirements for generator commissioning.	☐	☐
Field Verification		
1. Protective Relay Coordination confirmed.	☐	☐
2. Revenue Metering Installation completed and checked. Attach BC Hydro Metering Checklist.	☐	☐
3. Local Operating Order approved by BC Hydro and the Generator. Generator and Control Centre have copies.	☐	☐
4. Electrical Inspection Approval attached.	☐	☐
5. Professional Engineer's declaration(s) that the Generator's Facilities have been designed, constructed, and tested to a state suitable for generator commissioning in accordance with prudent electrical utility practice.	☐	☐
6. BC Hydro facilities ready.	☐	☐
7. Grid Operations approval to energize for generator commissioning received	☐	☐

Provide explanation if "No" has been checked for any item above.

The undersigned do hereby declare that the Generator's Substation is compatible for interconnection with the BC Hydro system for the purposes of commissioning.

_____	_____	_____	_____
(Generator or Delegate)	*Date*	*(BC Hydro Field Coordinator)*	*Date*

G.3 Requirements for "Declaration of Compatibility – Generator (Operating)"

The compatibility of generation (operating) describes conditions that must be satisfied before the PG's facility can be connected to commercially generate electricity

Declaration of Compatibility
Generator (Operating)
Generator's Facilities

Generator:

Project:

The Generator shall design, construct, own, and maintain the Customer's Facilities.

	Yes	No
Interconnection		
1. Executed Interconnection Agreement	☐	☐
2. BC Hydro has reviewed the Generator's proposed facilities to confirm compliance with BC Hydro's technical requirements for generation operation.	☐	☐
Field Verification		
1. Protective Relay Coordination confirmed.	☐	☐
2. Revenue Metering Installation completed and checked. Attach BC Hydro Metering Checklist.	☐	☐
3. Local Operating Order approved by BC Hydro and the Generator. Generator and Control Centre have copies.	☐	☐
4. Electrical Inspection Approval attached.	☐	☐
5. Professional Engineer's declaration(s) that the Generator's Facilities have been designed, constructed, and tested to a state suitable for final operation in accordance with prudent electrical utility practice.	☐	☐
6. BC Hydro facilities ready.	☐	☐
7. Grid Operations approval to energize for generator operation received.	☐	☐

Provide explanation if "No" has been checked for any item above.

The undersigned do hereby declare that the Generator's Substation is compatible for interconnection with the BC Hydro system for operating purposes.

_____	_____	_____	_____
(Generator or Delegate)	*Date*	*(BC Hydro Field Coordinator)*	*Date*

H PERMISSIBLE VOLTAGE DIPS - BORDERLINE OF VISIBILITY CURVE